A

DISSERTATION, &c.

86d

A
DISSERTATION
UPON THE
PHILOSOPHY
OF
LIGHT, HEAT, AND FIRE.

IN SEVEN PARTS.

By JAMES HUTTON, M.D. & F.R.S E.

R

EDINBURGH:
PRINTED FOR MESSRS CADELL, JUNIOR,
AND DAVIES, LONDON.

1794.

4

MVSEVM
BRITAN
NICVM

PREFACE.

WHEN I began this Diſſertation, I had only in view to repreſent, to the Royal Society of Edinburgh, the importance of examining ſtrictly thoſe unexpected phenomena, which had occurred in the accurate experiments of M. de Sauſſure and M. Pictet; and to ſhow, that thoſe experiments did not neceſſarily confute the general theories of Heat and Cold, with which, at firſt view, they ſeemed to be inconſiſtent.

But, in purſuing the ſubjects heat and cold, that of fire, or the phenomena of burning

ing bodies, naturally occurred, as being ſtrictly connected with the principles upon which I then was reaſoning, and therefore a proper ſubject for inveſtigation in this treatiſe. Thus, the purſuit of one object has led to the examination of another; and thus different ſubjects have ſucceſſively preſented themſelves for diſcuſſion. It is therefore neceſſary to divide this Diſſertation into ſeveral parts, and to have theſe methodically arranged according to the order in which the connected ſubjects had naturally occurred.

In Diſſertations upon Subjects of Natural Philoſophy, when treating of the tranſmiſſion of heat, I mentioned the ſubject which is to be examined in this treatiſe; and I ſtated ſhortly the principles upon which I am now to reaſon, in developing a theory which will explain many of the appearances of heat and fire.

It was only M. de Sauſſure's experiment with regard to heat, which I had then in view, not having heard of M. Pictet's experiment with regard to cold. It is this laſt experiment, in which there is an appearance of reflected cold, that principally attracts the attention of philoſophers, the appearance being ſo anomalous. But ſurely this laſt experiment is only to be properly explained, upon principles which are to be acquired by underſtanding M. de Sauſſure's experiment with regard to the appearance of reflected heat. This, therefore, forms the firſt object in the preſent inveſtigation.

The doctrine, which is contained in this treatiſe, is intereſting to philoſophy; but, it is of different kinds, and may not all, perhaps, be ſeen, by different perſons, in the ſame light. To men of ſcience, *i. e.* who purſue particular branches of knowledge without embracing the whole, the firſt and fourth parts of this Diſſertation, which treat of ſcience in general, and the means of purſuing knowledge, may perhaps appear unneceſſary or ſuperfluous, while the other parts, in which I endeavour to explain particular phenomena, may appear to be of ſome importance. They may perhaps conceive that I have written the firſt and fourth parts merely as introductory, or as ſubſervient to thoſe in which I give experiment and explanation of appearances. My view is very different; I wiſh to engage men of ſcience, *i. e.* thoſe who have ſufficient knowledge of the particular branches of ſcience, to employ their acquired talents in promoting general ſcience, or the knowledge of that great ſyſtem, where ends and means are wiſely adjuſted in the conſtitution of the material univerſe; and I only, or chiefly, give thoſe explanations of phenomena as an illuſtration of the doctrine, which upon all occaſions I have held, with regard to the purſuit of ſcience and philoſophy.

Philoſophy ſurely is the ultimate of human knowledge, or the object at which all ſcience properly ſhould aim; every ſtep in ſcience, therefore, ought to be valued, in ſome meaſure, as it tends to bring about that end. Science, no doubt, promotes the arts of life; and it is natural for human wiſdom to improve thoſe arts. But, What are all the arts of life, or all the enjoyments of the mere animal nature, compared with the art of human happineſs,—an art which is only to be attained by education, and which is only brought to perfection by philoſophy! Man muſt learn to know himſelf; he muſt ſee his ſtation among created things; he muſt become a moral agent; and he muſt inquire after that ſyſtem in which he had been intended either for happineſs, or for miſery, as an end. This is what he has to learn; but, it is only by ſtudying *things in general* that he may arrive at this perfection of his nature.

It is impoſſible to form the idea of *generals* except upon the knowledge of *particu-*

lars; and, it is upon particular phyſical and mathematical truths that natural philoſophy muſt found its principles. To philoſophiſe, therefore, without proper ſcience, is in vain; although it is not in vain to purſue ſcience, without proceeding to philoſophy. The truths of ſcience are to philoſophy what the beams of wood, and the hewn ſtones, are to a building. The greateſt collection of thoſe materials does not form a building, although that building cannot proceed without thoſe neceſſary materials; the building requires the operation of the architect, to regulate and to adjuſt the whole.

A man of ſcience and a philoſopher are different things, although they both proceed in reaſoning ſcientifically, after having diſtinguiſhed their ideas. The purpoſe of the one, although occaſionally extenſive, is naturally limited, in having a ſubject which is then particular; the purpoſe of the other again, though not perhaps unlimited, is, in relation to the finite Being man, a univerſal, and employs that general knowledge which ſcience had provided, in order to procure ſomething ſtill more intereſting to the perſon, who thus is made for a ſuperior enjoyment. Now, this enjoyment is the ſeeing that there is order and deſign in nature; and, the finding that there is wiſdom and benevolence in that deſign, as well as power which is unlimited. Here is the beſt purpoſe for ſtudying nature;—here is that love of wiſdom which is to make the intellectual Being happy. Now, it is by obſerving facts, by generaliſing truths, and by judging on the whole of things, that this knowledge of nature,—this confidence in the CAUSE of our exiſtence, is to be attained.

When the great Bacon led the way to natural philoſophy, phyſical ſcience was deficient; it had not analyſed natural objects, and generaliſed thoſe events which conſtitute the actual ſtate of things; it had not therefore any principle whereon to found a general ſyſtem or deſign. But, men would generaliſe; they then imagined facts, inſtead of making accurate obſervation. Upon ſuch principles as theſe, What ſort of philoſophy could be built? At preſent, Natural Philoſophy is in a very different ſtate; facts are not wanting; we rather have occaſion to diſpoſe of thoſe materials which we poſſeſs. When Natural

Philoſophy, for want of ſolid materials, built on ſuppoſition and conjecture, the edifice tumbled down in one place as it was raiſed in another; we now have ſome ſolid building which will ſtand; and, we have alſo much materials with which to build.

But, there ſeems to be an opinion prevailing, viz. That it is too ſoon to philoſophiſe;—that we have not at preſent ſufficient matters of fact (which are to be learned from experience,) in order to philoſophiſe with ſucceſs. That this is an ill founded opinion, will appear from the ſucceſs which Natural Philoſophy (however little advanced) has already had. Are we to wait until all particulars are known, before we generaliſe? This would be equally unwiſe as to attempt to generaliſe before we had particulars. It ſhould be conſidered, that the diſpoſing of one fact, that is, the putting it into its proper place in ſcience, or the general order of our knowledge, is doing more for natural philoſophy, than a thouſand experiments made without that order of connection or relation which is to inform the underſtanding.

The number of experiments, that are to be made, are infinite; but, there is only one experiment which, in every caſe, it is proper for us to make; and, it is only philoſophy or general knowledge which is proper to direct the making of that experiment. Thus, though natural philoſophy requires to have matter of fact, which is learned from experience, yet, the indefinite collection of facts does not conduct philoſophy;

ſophy; but, philoſophy neceſſarily directs the making of a proper experiment, which is required for the progreſs of the human underſtanding in phyſical inquiries. Therefore, the properly diſpoſing of one fact, or the formation of one ſcientific truth, in the generaliſation of our knowledge, is more valuable than the indefinite progreſs of experiment made without the proper purpoſe of philoſophy or a wiſe deſign.

I do not mean to ſay, that natural philoſophy can proceed one ſtep without the ſanction of experiment; we might as well have learned aſtronomy without viſion. The truth I wiſh to inculcate is this, That, in the one caſe as well as in the other, experience is the means; and, that it requires the ſcience of the ſubject in order to employ thoſe means to advantage. Therefore, natural philoſophy requires no leſs the *generaliſation* of the knowledge which we have acquired, than the acquiſition of *particular knowledge* is required for the purpoſe of that generaliſation.

My purpoſe is to ſhow the difference in the ſtate of ſcience and philoſophy ſince the time of Bacon. He ſaid properly,—Do not attempt to *generaliſe* until you have procured materials by obſervation;—Do not pretend to *philoſophiſe* until you have procured general truths on which to build your reaſoning.—Phyſical ſcience was in its childhood when he wrote; were he now to write he muſt hold another language; perhaps he would ſay,—To what purpoſe make thoſe experiments?—Is it not to generaliſe particulars ?—And, what is the uſe of generaliſing particulars ? Is it not to find the conformity of more general truths ! But, thoſe general truths are ſtill to be generaliſed, until we arrive at univerſals, which cannot be farther generaliſed. It is then that we may underſtand the wiſdom of nature, in ſeeing the ends which are effected, and perceiving the order of thoſe events, or ſeeing the means which are employed. This then is a progreſs that we never ſhould loſe ſight of; it is to ſee the order and deſign of Nature that we examine events, which of themſelves teach nothing. It is thus that we may ſee how to proceed in ſcience with the greateſt advantage; it is thus that we may become philoſophers,—men who ſee the wiſdom of nature,—men who are wiſe, in knowing how beſt to purſue the object of their deſire,—and, men who may ſtill be more wiſe, in knowing what object it is beſt for them to purſue.

The experiments of M. de Sauſſure and M. Pictet, which are to be examined in this diſſertation, were no doubt made with the moſt ſcientific view, in order to promote our knowledge of nature; but, the philoſophy of light and heat, which ſhould have conducted thoſe experiments, was, in my apprehenſion, too deficient to derive from them that benefit which otherwiſe would have infallibly followed thoſe well conducted experiments and accurate obſervations. The object of this Diſſertation is to ſhow, that, with the phyſical knowledge which ſcience had acquired, the philoſophy of light and heat might have led to other concluſions than thoſe which were formed on that occaſion; and therefore, that nothing is more dangerous to philoſophy, than the not employing properly the ſcience which we poſſeſs, or, the not reaſoning accurately from the phyſical principles which we have acquired.

We have a remarkable example of this, in that theory of fire or burning which has of late been formed, and, with ſuch plauſibility or appearance of truth, as has ſeduced men of ſcience. But, thoſe chymical philoſophers, who at the ſame time have greatly advanced ſcience, have not reaſoned as they ſhould have done upon their data; they have not reaſoned accurately from the ſcience which we poſſeſſed before their brilliant diſcoveries had enlarged the field of chymical knowledge. This is what I want to ſhow; and, this is a ſubject which I have already treated of in another place.

In my diſſertation upon the ſubject of phlogiſton, I have ſhown the error of the new antiphlogiſtic theory; for, there I have proved, That the light and heat of fire does not proceed from the condenſation of vital air in burning, or from any thing that might properly be termed *calorique*; but that it neceſſarily requires another cauſe, which may be properly termed *phlogiſton*. This was all I had in view at that time; I did not then attempt to diſtinguiſh, in the light and heat of fire, which of theſe was to be conſidered as the immediate effect of burning. I am now, in this diſſertation, to proceed a ſtep farther; for, I am to ſhow that, though heat be neceſſary, in general, to the burning of bodies or kindling of fire, it is not heat which is immediately produced in fire; but that it is the ſolar ſubſtance, lodged in thoſe phlogiſtic bodies, which is then made to emerge in light, and to excite that heat which appears on thoſe occaſions, as the effect of fire. If I ſucceed in this, then, not only will that antiphlogiſtic theory of fire be completely refuted, but the theory, which I had propoſed, will be thus more and more illuſtrated and confirmed.

But ſtill there is another part of this ſubject to purſue,—an inveſtigation moſt intereſting to Natural Philoſophy. This is, to examine that fixed light or principle of fire with regard to gravitation and *inertia*. Theſe are ſubjects upon which natural philoſophy at preſent has proceeded, and I believe muſt always proceed. But I have ſhown wherein thoſe principles have been aſſumed improperly, in making them too general *; and now, in the ſixth part of this Diſſertation, I am to add confirmation to that doctrine, from experience.

We only want farther to generaliſe the ſubject of light and heat, ſo far as it has been inveſtigated from the phenomena of fire, by comparing theſe with what may be found in examining the light which comes to us immediately from the ſun. Here I take a view of the conſtitution of light for the purpoſe of this world. This forms the ſubject of the ſeventh part, with which the diſſertation is concluded.

---

* See Subjects of Natural Philoſophy, Part III. Diſſ. I. and II.

CONTENTS.

CONTENTS.

* * *

Page

PART I.

General Obſervations with regard to the true manner of reaſoning in Phyſical Inquiries, illuſtrated in the preſent ſubject, Light and Heat - - 1

PART II.

A particular Inveſtigation of the Power of Light for exciting Heat in Bodies, in order to explain an anomalous appearance in an Experiment of M. de Sauſſure - - - - - 32

PART

Page

PART III.

A farther Application of the Principle of Inviſible Light to the Theory of Heat and Cold, with a view to explain M. Pictet's Experiment of Apparently Reflected Cold - - - - 57

PART IV.

An Examination of the preſent ſtate of Science reſpecting Light, Heat, and Cold; with a view to promote the Philoſophy of that ſubject - 101

PART V.

Light inveſtigated as the Principle of Fire in Burning Bodies - - 146

SECTION I.

Combuſtible Bodies examined with regard to the Nature of Burning - ibid.

Page

SECTION II.

Inflammable Bodies examined, with regard to the nature of Burning - 179

SECTION III.

Of Deflagration, Explosion, and Fulmination, in Burning Bodies - 197

SECTION IV.

Of the Emission of Coloured Light from Burning Bodies - - - 215

SECTION V.

Recapitulation and Conclusion - 227

PART VI.

Fixed Light, or the Principle of Fire, examined with regard to Gravitation and Inertia - - - 237

SECTION

Page

SECTION I.

The Solar Subſtance examined with regard to Gravitation - - 237

SECTION II.

The Solar Subſtance examined, with regard to Inertia - - - 256

PART VII.

Of the Solar Light compared with that of Fire - - - - 290

A
DISSERTATION
UPON THE
PHILOSOPHY
OF
LIGHT, HEAT, AND FIRE.

PART I.

General Obſervations with regard to the true manner of reaſoning in Phyſical Inquiries, illuſtrated in the preſent ſubject, Light and Heat.

I HAVE been induced to write this Diſſertation from a converſation which took place among ſome of the Gentlemen of this Society, concerning an experiment which ſeems to refute our theory of heat and cold. It was then propoſed to repeat and purſue ſimilar experiments, as they promiſe to give ſome new light in natural philoſophy. I now wiſh to conſider the ſubject in its preſent ſtate, in order to ſee how far we have any principle, for the explanation of certain phenomena which ſeem to be anomalous.

But, principally, I wiſh to ſhow the erroneous, or inconſequent way of reaſoning, which has prevailed in phyſical inveſtigation, owing to the not analyſing ſufficiently our natural, compound, animal ideas; it is thus that we proceed to generaliſe things which are not then properly diſtinguiſhed.

One of the facts, which is the ſubject of thoſe propoſed experiments, was diſcovered in ſome meaſure by accident; at preſent, it is only an inſulated event. The object of ſcience, therefore, with regard to thoſe anomalous appearances, is to place them in the order of nature, or that in which they muſt ſtand in relation to other things. In that caſe, ſuch an event would be not only underſtood in being generaliſed, but it would become a principle, in ſerving to explain other events.

In the ſcience of phyſics, the making an experiment is to inquire, at nature, concerning the truth of a conceived propoſition; without that previous conception, of order in the courſe of nature, there could not be experiment, which implies deſign. Thus, there muſt be a certain theory, or generaliſation, in the mind of the perſon who makes the inquiry; and, it is only in proportion as the theoretical propoſition and experiment are juſtly formed, that ſcience will be actually advanced in the reſult. Therefore, it is ſo neceſſary to underſtand the ſubject about which we are to inquire; otherwiſe, the reſult of the experiment, or information of nature, might only ſerve to miſlead our theory, as will be exemplified in the courſe of this inquiry.

If experiment, which in the ſcience of phyſics is the ſupreme authority, ſhall prove to be in oppoſition to the principles upon which our theory of heat and cold is built, as from what has been alledged it ſeems to be, in that caſe, I would wiſh to be the firſt who ſhould renounce thoſe erroneous principles. But, Are we, upon the faith of a ſolitary experiment, to abandon our theory of heat and cold, which is the generaliſation of a broad experience? Are we to build a new theory ,upon a ſingle fact, before this fact is properly analiſed, in ſeeing every circumſtance with which it is connected, and before comparing that analiſed fact with every other event with which it ſhould agree? and, Are we to ſuſpect our principles as being falſe, when we have diſcovered a fact which ſeems to be anomalous? This would be no other than the abſurdity of being, at the ſame time, both credulous and ſceptical.

But, while we do not ſuffer ourſelves to be led aſide by novelty, let us alſo avoid the oppoſite extreme; and let us not, from an inordinate confidence in our theory, neglect a fact which may procure us ſome new principle in our ſcience.

Firſt, let us endeavour to ſtate the caſe, in order to form diſtinct ideas of the ſubject to be aſcertained by experiment; for, without the clear diſtinction of things truly diſſimilar in their nature, as well as the proper aſſimilation of thoſe which ought to be generaliſed in our ſcience, we would but confound our knowledge, proceed in error, and lead at laſt to inconſiſtency in our concluſions. Thus, inſtead of arriving at philoſophy, our ſcience would only betray us into ſcepticiſm.

Philoſophy neceſſarily reſts upon this principle, That nature is uniform or conſiſtent; therefore, an apparent inconſiſtency in our experience is not to be raſhly imputed to the order of nature; nor is ſcience to be blamed for the diſcordant opinions of generaliſing men: The errors or inadvertencies of man, ſo far from being a proper ground for ſcepticiſm, muſt contribute for eſtabliſhing the certainty of ſcience, when theſe are properly corrected. Therefore it is ſo important to underſtand our principles which are founded on experiment, as well as to make experiment by which our theories are to be tried; for, without all that accuracy which is required in analiſing and in generaliſing truths, the neceſſary reſult of our reaſoning muſt be either abſolute error in our ſcience, if nature is ſuppoſed uniform, or apparent inconſiſtency in nature, if we entertain not any diſtruſt with regard to our ſcience.

Nothing is more pernicious to philoſophy than the carrying our vulgar notions unanaliſed, into ſcience, where they may be confounded with principles which are of abſolute authority. The oppoſite of that error, is to form abſtract notions of action and efficiency, without being founded on matter of fact, from whence every active, as well as every paſſive idea, muſt have its origin, and therefore to which, in ſcience, all our principles muſt be referred.

Above all things, ſcience requires the moſt diſtinct conception of thoſe terms which are employed in our reaſoning; for, without ſcientific definition, and a clear analyſis of our compound ideas, How are we to reaſon accurately in phyſics, any more than in mathematics? whereas, by analiſing every compound idea which we have from nature, ſo as to arrive at the firſt principles of thoſe diſtinguiſhed things, and by defining all thoſe principles on which we reaſon in aſſimilating our diſtinguiſhed ideas, as we do in the ſcience of magnitude, figure, and proportion, we ſhould then proceed with no leſs certainty in that of weight, of heat, and of cold.

There is perhaps no ſubject in which

the language and ideas of men are more vague, or diſtant from true ſcience, than in thoſe of heat and cold. The reaſon of this will not be difficult to aſſign. Heat is a term which is applied in different caſes; for, it is both a principle of action in external things, and a principle of paſſion in our ſenſitive mind. But this is only a part of that intricacy with which this apparently ſimple ſubject is neceſſarily involved; for, when heat is a principle of action in external things, there are two different effects which occaſionally follow this principle as a cauſe. Firſt, bodies are by heat diſtended or expanded in their volume; here is one diſtinct effect. Secondly, without being thus diſtended by heat, bodies, in receiving that diſtending cauſe, are made to loſe their hardneſs or concretion, and become fluid in their ſubſtance; here then is an effect diſtinctly different from the other; and both of theſe are perfectly different from the feeling of heat and cold, which is the immediate information of the ſenſe.

The idea of heat is therefore a thing more and more complex in its nature, in proportion as men of ſcience extend their views beyond the more limited notions of the vulgar, and inquire after cauſes; and, the juſt idea of heat is only to be attained after the moſt accurate analyſis of our phyſical knowledge. No wonder, therefore, that we ſhould find the opinions of natural philoſophers ſo very different, conſequently erroneous, concerning the nature of heat.

Man, in his ſcientific progreſs, is naturally liable to error; not from the defect of nature, nor from the uncertainty of ſcience, but from the ſuperior nature and conſtitution of his growing intellect, which is made to proceed, firſt, by forming opinions with regard to things, and then by reaſoning from thoſe opinions or principles which he had formed.

Having thus to proceed upon his natural animal knowledge, firſt, in analyſing it, and finding inequalities and diſſimilarities; and, ſecondly, in generaliſing thoſe diſtinguiſhed things, by finding a certain order of equality and ſimilarity in things which are diverſe, he then reaſons hypothetically, in forming propoſitions and concluſions, by employing various *media* for the diſcovery of truth. Is there any wonder, then, that error ſhould creep into the reaſoning of our ſcience, when human underſtanding is only made to proceed by ſeeing truth and falſehood, by diſtinguiſhing fitneſs and unfitneſs? Surely there is but one way to arrive at truth; and this requires to have the power of diſcovering error. Nothing, therefore, is ſo important to the progreſs of our ſcience, as to ſee thoſe falſe ſteps of reaſon in which the path of truth had been forſaken.

The ſubject which we are here to examine is that of heat and cold, of light and burning. Perhaps there is no ſubject in natural philoſophy in which we ſhall find more reaſon to return upon our ſteps, to analyſe our knowledge, and to correct thoſe vulgar errors, or erroneous notions, into which we may have fallen. This then is an object of which we are not to loſe ſight.

In treating of this complicated ſubject, I propoſe to ſhow, firſt, that though philoſophers have learned much with regard to the affections of light by bodies upon which that moving ſubſtance falls, yet, that much is to be learned with regard to the reciprocal affection of thoſe bodies, in conſequence of the received light. Secondly, that, although the ſcience of heat has made a great ſtep, not only in meaſuring degrees, but in comparing quantities of heat which are to have their ſpecific effect in bodies; yet, our natural philoſophers, with all the light of this improved ſcience, appear to entertain the moſt inconſiſtent ideas in relation to this ſubject, heat, as a principle of bodies, or as a quality in nature. Thirdly, that, although the nature of cold is not to be diſputed in a philoſophy that admits the exiſtence of heat in various degrees, yet, no philoſopher has a right to form of this a general principle, for the explanation of appearances, while he cannot explain how a negative cauſe ſhould be attended by a poſitive effect.

Laſtly, I propoſe to ſhow, that, although the uſe of fire is brought to ſuch perfection in the various arts of life, philoſophers, who have alſo greatly advanced the ſcience of chymiſtry, have committed a miſtake, perhaps the moſt pernicious to natural philoſophy, in aſcribing the appearances of burning to a cauſe or principle directly oppoſite to what is true. In thus aſcertaining the true principle of fire, or proceſs of burning, we ſhall alſo decide a point which has been of late the ſubject of much ſcientific controverſy, viz. that there is truly in bodies a ſubſtance, which may be properly named *phlogiſton*, as being the cauſe of that light and heat which accompany burning.

We are now to take a view of the actual opinions of our philoſophers with regard to this ſubject, heat; this being the more neceſſary, as I have thoſe opinions to refute. This will alſo lead us properly to thoſe experiments which I am to endeavour to explain by a new theory with reſpect to the powers of light.

The great geometrician, M. Lambert, conſiders heat as a body capable of ſpecific gravity or levity, *i. e.* a body more or leſs expanded. His words are, "Voyons à "preſent, de quelle maniere on pourra "enviſager la loi ſuivant laquelle la cha-"leur decroit en montant. Avant toute "choſe il s'agit de ſavoir d'où vient que "la chaleur monte. Ici, je ne ſais d'autre "raiſon, ſinon que le feu eſt ſpecifique-"ment plus léger que l'air." This is not conſidering *heat*, but the effects of heat in bodies that are *heated;* and this is perhaps the idea of almoſt all the natural philoſophers who have written upon the ſubject;

although ſome of them modify that idea, in conſidering its actions or affections in relation to other bodies. In order to ſee this, I will now give what M. de Sauſſure has wrote upon the ſubject, Voyages dans les Alpes, tome 2.

" § 924. M. De Luc croit auſſi, comme " M. Lambert, que le fluide igné eſt plus " rare dans les hautes regions de l'air; " mais par une raiſon bien differente. Le " grand géometre de Berlin a cru que le " feu ſe raréfioit dans le haut de l'athmo- " ſphere par l'action de la peſanteur de " l'air; M. De Luc croit qu'il ſe condenſe " dans le bas par ſa propre peſanteur. M. " Lambert conſidere le feu comme un flu- " ide diſcret en mouvement, qui ſe raréfie " par l'accélération de ſa viteſſe; et M. " De Luc le compare à une fluide continu, " dont les partiés ſe condenſent en ſe com- " primant mutuellement."—Let us now examine this idea, in order to ſee how far it is juſt.

This manner of conſidering heat, as a body poſſeſſed of certain qualities, is not conſiſtent with our vulgar notions, in which bodies are conſidered as being abſolutely hot or cold ; nor is it a ſcientific attempt to analyſe thoſe vulgar notions or natural ideas to their conſtituent principles. Heat, as an external thing, is only a quality of bodies ; it therefore cannot be that thing which then is qualified ; this would be loſing the diſtinction of the agent and the patient, the thing heat as a cauſe, and the conſequence of that thing as an effect. The more, then, that we ſhould reaſon upon ſuch a miſtaken principle, the more we would proceed in error.

Now, to ſuppoſe us knowing heat by any other means, beſides its effect in the qualifying of bodies, and in the exciting of our ſenſation, is to be ignorant of the ſubject about which we then are reaſoning. But, How pernicious to ſcience muſt be ſuch reaſoning, in which heat and cold are conſidered as ſubſiſting in a bodily ſhape! The vulgar notion, that bodies are either hot or cold, though not a ſcientific idea, or perfectly analyſed, cannot be ſaid to be erroneous; for, though the body is not hot or cold, it is the cauſe of our ſenſation when we thus are made to feel; whereas, to conſider heat and cold as things with ſenſible or perceptible qualities, ſubſiſting independent of the body that may be ſo qualified, is purely in error; or, it is inconſiſtent with other conceptions which we muſt form in relation to that ſubject.

In phyſical things, where there is ſomething actual, we know the effect or event, that is to ſay, the information of ſenſe, by which the action is *judged* with infallibility *; but we cannot know the thing that acts, *when we are thus informed* †; this would be knowing how we know, which is impoſſible. Let us ſee then what we do in this caſe.

---

* See an Inveſtigation of the Principles of Knowledge, Part II. Sect. VIII. Chap. X. & XI.

† Ibid. Sect. X. Chap. V.

Upon certain occaſions, as when we approach the fire, our ſenſe informs us in a particular manner; and this we name *heat*, which is then purely a ſenſation. But, at the ſame time, we perceive a certain concomitant event, as the effect of heat in bodies, which we conſider as the *heat of diſtention*, or ſenſible heat; and, in like manner, we diſtinguiſh another effect, which may be properly named the *heat of fluidity*, or latent heat. Now, in all thoſe caſes, we know nothing more about this thing which is the cauſe; we judge with certainty a thing to have acted; and, in thoſe actions, we find rules, by which they are aſſimilated or generaliſed; we then name thoſe rules of action the *laws of nature.* It is this *nature*, then, which is the external thing; *this* is the cauſe of heat, and light, and gravitation; and, *this* is the agent by which we are informed of power and wiſdom infinitely ſuperior to that of which we are conſcious in ourſelves. But, from all this, we have no right, *i. e.* no reaſon, to *figure* to ourſelves either heat, or light, or gravitation, which are not bodies, but active powers ; it would be no leſs prepoſterous to ſuppoſe ſound to be coloured, than to ſuppoſe heat having volume, although it be the cauſe of volume in bodies.

In that kind of reaſoning which is conſidered as the common ſenſe of mankind, the fire is conſidered as being hot and red, and ſnow is thought to be cold and white ; but, when in ſcience we come to analyſe thoſe common notions, we find our firſt generaliſed judgments inconſiſtent with matter of fact ; it is then that we ſay, without a paradox, "That the fire is not hot, "nor the wall white ;" although we truly are informed by light and heat on thoſe occaſions. But philoſophers, even the moſt ingenious, miſtaking the nature of our ſcience and abſtraction, as Dr Berkeley has done, have laid a foundation for ſcepticiſm in caſes where our knowledge is moſt evident. For, with regard to that pretended paradox of Dr Berkeley, heat and whiteneſs are only paſſions in our mind; of this then we have the moſt certain knowledge; and ſurely ſome thing muſt act on thoſe occaſions, when we are made to receive information by ſenſe, although we have no farther knowledge of that thing. Now the object of ſcience and philoſophy is to inveſtigate the nature of thoſe external actions, when we are informed of light, of heat, and of cold.

Our author thus proceeds: "Enfin, dans la queſtion ſur l'identité du feu et de la lumiere, que M. Lambert n'avoit pas oſé réſoudre, mais vers l'affirmative de laquelle on voit bien qu'il penchoit, M. De Luc ſe décide pour la négative, et il ſoutient que la lumiere eſt un agent incapable par lui-même de réchauffer les corps; mais qui met en mouvement le fluide igné qu'ils renferment, et qui agit avec plus d'efficace auprés de la ſurface de la terre, parce que ce fluide élaſtique et peſant y eſt plus condenſé qu'à une plus grande hauteur." Hiſt. de la Terre, Tom. V.

Here is a queſtion concerning theſe two cauſes, light and heat; viz. What theſe two things are of themſelves, independent of appearances or of our knowledge concerning them, and how they operate in producing their effects. Now it muſt be evident, that ſuch a queſtion is unſcientific, and idle or in vain, ſo far as we cannot have *immediately* the knowledge of any phyſical cauſe; this we only judge from the effect, which is then the proper object of our knowledge. We know the nature of nothing farther than as it appears to us; but, light and heat never appeared to us in any bodily ſhape; theſe are abſtract ideas formed by us reaſoning from what appears; and it is impoſſible that we can have any other information, of thoſe two cauſes light and heat, than that which is given us by ſenſation. It is true that, from the actual information which we have by means of the ſenſe, we are qualified to draw the moſt poſitive and aſſured judgments with regard to the action and efficiency of thoſe two cauſes of our knowledge, in like manner as we do with reſpect to gravitation or the cauſe of weight in bodies; but, though we are thus properly qualified to purſue ſcience without any error or dubiety, it is not always that ſcience is thus purſued. We ought therefore to be cautious how we conclude that light and heat, the cauſes of our ſenſe, truly exiſt in the manner in which we may have formed to ourſelves thoſe abſtract ideas, in aſcribing to them qualities which they have not.

Let us now ſee the idea of M. de Sauſſure in relation to this ſubject; it follows immediately that which has here been quoted.

" § 935.

" § 935. Pour moi, j'avoue que malgré l'autorité de ces deux phyſiciens célebres, je ne ſaurois regarder le feu comme un fluide aſſez libre et aſſez independant, pour pouvoir, ou s'élever avec rapidité par ſa légereté ſpécifique, ou ſe condenſer ſenſiblement par ſa propre peſanteur. Il me ſemble, que plus on a approfondi les phénomenes et la theorie de cette matiere ſubtile, et mieux on s'eſt convaincu qu'elle eſt liée avec tous les corps par une affinité ſi grande, que tous ſes mouvemens ſont déterminés, ou du moins puiſſament modifiés par cette affinité.

" Je crois que l'on peut appliquer au feu élémentaire ce que j'ai prouvé de l'eau dans le Chapitre I^{er}. du premier de mes *Eſſais ſur l'ygrométrie.* Il eſt prouvé que les corps différent entr'eux, non-ſeulement par la quantité d'eau et de feu principe qui entre dans leur combinaiſon, mais encore par la force avec laquelle ils attirent à eux, et abſorbent dans leurs pores l'eau et le feu qui ſont répandus dans l'air. Je crois avoir démontré cette verité par rapport à l'eau, et les belles experiences de M. Crawford, de même que les experiences plus exactes de M. Lavoiſier et De la Place, l'ont auſſi démontré par rapport au feu. Lors donc que ce fluide, degagé par la combuſtion, ou par tout autre cauſe, tend à ſe répandre ou à ſe diſſéminer, tous les corps dans la ſphere d'activité deſquel il ſe trouve, tendent à s'emparer, et ils en abſorbent des quantités qui ſont en raiſon directe de leur affinitè avec lui, et inverſe de ce qu'il leur manque pour être en equilibre avec les corps environnans. Or, il ne paroît pas que dans cette eſpece de répartition, la ſituation des corps, relativement à l'horizon, ait d'autre influence que celle que lui donnent les courans produits par la dilatation de l'air et par la légereté que produit cette dilatation."

Here our author takes a much more ſcientific view of heat, in underſtanding

the different capacities of bodies in relation to heat, and the valuable doctrine of latent heat, diſcovered long ago by Dr Black, and lately verified in an ingenious manner by M. Lavoiſier and De la Place; although theſe philoſophers ſeem to have miſunderſtood that principle, which, in the doctrine of *calorique*, they have groſsly miſapplied. Our author here alſo very properly corrects the erroneous notions of M. Lambert and M. De Luc, with regard to the aſcending or deſcending of heat. Neverthelеſs, with all his enlightened views, M. de Sauſſure would ſeem to entertain but an imperfect or inaccurate idea with regard to the nature of heat, in aſcribing to it qualities which it has not, or which properly belong to another thing.

What leads me to be of this opinion, is that which he has ſaid in this ſame chapter, where he has given us a moſt beautiful experiment, the proper ſubject of this diſſertation. It is that of affecting the thermometer by the reflected radiation from a body, which is then heated far below the intenſity neceſſary for incandeſcence. But, this radiation from the warm body, M. de Sauſſure conſiders, not as any ſpecies of light, but as heat moving from a body or independent of bodies; and it is this opinion which I think is inaccurate, unſcientific, or not conſiſtent with all other phyſical truths. We find that opinion in what he has ſaid farther upon the ſubject, § 926.

" Je reviens à ce que j'ai dit des obſtacles que les corps, dans lequels le feu élémentaire eſt engagé, paroiſſent mettre à la liberté de ſon aſcenſion ou de ſa condenſation. Peut-être m'objectera-t-on l'experience connue d'une corp combuſtible, allumé à la diſtance de 20 ou 24 pieds, par la repercuſſion et la concentration de la chaleur d'un charbon ſitué entre deux miroirs concaves. Je dis *de la chaleur*, car M. Lambert a très-bien fait voir que ce n'eſt point ſeulement la repercuſſion de la lumière ou de la *chaleur lumineuſe* de ce charbon, mais celle de ſa *chaleur obſcure* qui produit cette inflammation; puiſqu'il a éprouvé qu'en raſſemblant au foyer d'une grande lentille la lumière d'un feu très-ardent, allumé au foyer d'une cheminée, on obtenoit à peine une chaleur ſenſible à la main."

He then ſays, in a note, " On lit dans les Memoires de l'Acad. des Sciences pour l'année 1682, une experience analogue de M. Mariotte." " La chaleur du feu réfléchie par une miroir ardent eſt ſenſible " à ſon foyer ; mais ſi l'on met une verre " entre le miroir et ſon foyer, la chaleur " n'eſt plus ſenſible."

" M. Scheele a fait auſſi des experiences analogues, très-interreſſantes, qui mériteroient bien d'être répetées et ſuivies."

In making that experiment long ago, I found that it was not preciſely as Mr Scheele has repreſented it, although it was ſuch as might have led him into that opinion. It appeared to me that the light of the fire truly paſſed through the glaſs, and affected the thermometer in the ſame manner as if the glaſs were not interpoſed; with this difference, indeed, that the intenſity of the heat was very conſiderably diminiſhed, ſo much as might impoſe upon an inadvertent obſerver. In this caſe, however, the juſt concluſion to be formed, is this, That the heat is more diminiſhed, than in proportion to the apparent diminution of the light in paſſing through the glaſs. But, What an erroneous theory has Mr Scheele founded upon that miſunderſtanding, or inaccuracy in ſtating the caſe of an experiment!

This extinction, however, of the light in paſſing through glaſs, is not our immediate object of inquiry. The thing we are now more particularly concerned with is the diſtinction, which M. de Sauſſure has made, of *chaleur lumineuſe* and *chaleur obſcure*.

ſcure. He reſumes as follows, on the reſult of that experiment of his and M. Pictet; and this will bring us directly to the point which is to be the ſubject of diſcuſſion.

" Il y a donc eu dans cette experience huit degrés de dilatation produit par la repercuſſion de la chaleur obſcure. Nous avons repété pluſieurs fois cette épreuve à jours différens et avec différens thermometres, et les réſultats ont toujour été à très-peu-près les même, au moins quand on tenoit le thermometre bien exactement au foyer du miroir; car pour peu qu'il s'écartât de ce foyer, il revenoit à la température du reſte de la chambre; et cette circonſtance même démontre que cette dilatation étoit bien le produit de la chaleur réfléchie par le miroir.

" Il ſembleroit donc ſuivre de cette experience que le fluide igné, le principle de la chaleur proprement dit, traverſe avec facilité une couche d'air de 12 pied d'épaiſſeur, et que par conſequent on peut ſuppoſer à ce fluide une aſſez grande liberté pour s'élever par la preſſion de l'air, ou ſe condenſer par ſon propre poids."

Here it is evident, that M. de Sauſſure conſiders the principle of heat as a fluid diſtinctly different from that of light; and that this igneous fluid may be moved to and from bodies, after the manner of light, although theſe two things are perfectly different. Now ſuch an opinion, as that heat is a thing eradiated and reflexible, or that heat may be moved through ſpace without body, are, according to our theory, erroneous notions, which philoſophy or more perfect ſcience muſt correct, at leaſt, they are notions which we are by no means warranted, in our philoſophy, to entertain.

In no ſenſe can this radiant and reflected ſubſtance be termed *obſcure heat*. In the firſt place, it is the *ſenſible* and not the *latent*

tent heat of bodies which we are now conſidering; ſecondly, this heat was not obſcure, although not viſible, in the body from whence it had been eradiated; and now, after being eradiated and reflected, it is no leſs ſenſible than it was before. The term *obſcure*, therefore, is in this caſe inapplicable, or a word without a meaning. But, let us ſuppoſe this eradiated and reflected ſubſtance to be light,—a ſubſtance which moves through ſpace independent of body, and a ſubſtance which we know to be eradiated and reflexible,—in that caſe, there would be great propriety in the application of the term *obſcure;* and then, the meaning of that term would be, That here were light, which, though eradiated and reflected, did not give viſion, or affect the ſenſe, in its uſual manner.

Heat, with reſpect to our ſenſe, is a certain feeling, but, in bodies, it is the cauſe of dilatation, and of fluidity. But here is an experiment, in which heat has been thought to be a thing eradiated and reflected. If this ſhall be admitted, we muſt abandon our theory of light and heat. Before, however, admitting that ſuppoſition of reflected heat, there is much to be conſidered; and, it is the object of this diſſertation, to point out that which is to be conſidered on this occaſion.

PART II.

A particular Inveſtigation of the Power of Light for exciting Heat in Bodies, in order to explain an anomalous appearance in an Experiment of M. de Sauſſure.

IN the Diſſertations upon ſubjects of Natural Philoſophy, I have endeavoured to eſtabliſh the true nature of heat, by inveſtigating the various events in which that active power is made known, and by diſtinguiſhing the different effects of which it is the cauſe. I have there alſo diſtinguiſhed the different principles of action upon which the effects of heat and cold proceed, or which belong to the ſolar ſubſtance on the one hand, and to the gravitating matter of this earth on the other; and I have endeavoured to inveſtigate the comparative ratios of the growing and diminiſhing intenſities obſerved in thoſe ſeveral rules of action. Thus, in the effects of heat and cold, there are diſtinguiſhed two abſolutely different principles of action, as well as different rules of variable intenſity; by the one, the diſtenſion and fluidity of bodies are procured, while condenſation and concretion are properly the effects of the other. Thus, in the conſtitution of this globe, compoſed of thoſe different kinds of matter, there is eſtabliſhed an alternate prevalence of the various powers which are ſo properly oppoſed; and thus the complicated purpoſes of this World are ſo regularly, ſo effectually, fulfilled.

We conceive a ſubſtance to be continually radiated from the ſun, to animate this globe, or to make it of a dead maſs of gravitating and concreted matter, which it is naturally, a living world producing plants and animals; this influence, then, is properly light, of which it is neceſſary to form a juſt idea, in diſtinguiſhing it from every other thing. In thoſe diſſertations, heat is

repreſented

repreſented as another modification of that ſolar ſubſtance in a body; it is a combination of the ſolar ſubſtance with gravitating matter; and it is in this combination that heat properly ſubſiſts. By heat, a body is either increaſed in its volume, or diminiſhed in its hardneſs and concretion; and, by cold, a fluid body is either made to concrete, or to be contracted in diminiſhing its volume; but to ſuppoſe heat moving without body, or reflected according to the laws of light, is certainly an idea that would diſgrace ſcience; for, it would be confounding things which are to be diſtinguiſhed, namely, the influence or emanation from the ſun, which is light, and the effects of that influence in bodies, which is heat.

Light is a thing conceived to be in motion; and it is from the ſenſible effects that we judge light to have moved, as well as to be compoſed of ſeveral diſtinct ſpecies: ſcience has even arrived at meaſuring the velocity of light. In like manner, we feel heat, and judge of the tranſmutable effects of heat in bodies. In the doctrine of latent heat, again, we have arrived at the art of meaſuring certain quantities of heat, and thus to compare the commutable effects of heat in bodies.

Thus we have the moſt diſtinct ideas of light and heat, however abſtract and complicated may be thoſe ideas. Therefore, when we ſhould ſuppoſe light lodged in a body and diſtending it, like heat; or when we ſhould ſuppoſe heat moving from a body and changing place in ſpace, like light, we would then either expreſs our juſt ideas falſely, or introduce falſe ideas into our ſcience. But if we ſhould employ ſuch falſe ideas for the explanation of natural phenomena, what are we thus to expect?—not to ſee the wiſdom of nature in the order of perceived events, but to ſubſtitute our own imagination in its place, and thus to corrupt our ſcience, by confounding truth and falſehood.

In M. de Sauſſure's experiment, there are certain phenomena to be explained; and, this explanation muſt proceed upon the laws obſerved in the action of light and heat. But, unleſs we have inveſtigated theſe laws, How is a matter of fact to be explained by them? Now, inſtead of attempting to explain an anomalous appearance by a falſe or miſconceived idea of things, let us employ this matter of fact, and endeavour to inveſtigate the laws of nature by finding the principle of the anomalous appearance, or to generaliſe the appearance by finding its affinity with other events of which we know the principle.

I am now to examine, firſt, the experiment of M. de Sauſſure, in relation to heat, in endeavouring to explain that phenomenon upon a new principle; and then I ſhall endeavour to confirm that theory, by means of an experiment made by M. Pictet in relation to that ſubject.

Long ago, I wrote a diſſertation upon

the nature of light; this, with ſome others, I intended to have publiſhed in the work already mentioned, but ſtopped ſhort upon account of the ſize of the volume. In that diſſertation, I had treated of a certain fact, with regard to the nature of light; and, this fact I am now to employ as a principle, for the explanation of the anomalous appearance in this experiment of M. de Sauſſure.

The part of that diſſertation, with which we are at preſent concerned, is the nature of the red ſpecies of light. This is found to be very different from ſome of the other ſpecies. But, what is particularly applicable to the preſent ſubject, is the peculiar property of this ſubſtance for the producing of heat in bodies. Thus it is the different ſpecies of light that we are now to conſider, with regard to their reſpective powers of affecting the ſenſe and heating bodies. We may thus perhaps acquire a principle of action that may be applicable in explaining natural phenomena.

At preſent we want to know, how far there may be acknowledged a ſpecies of light, which ſhould be capable of producing heat in bodies, without affecting our ſenſe of ſight. Now, for that purpoſe, we muſt inquire at nature, in making obſervation with regard to the regular courſe of thoſe events.

It muſt be evident, that, having a certain meaſure of light, by means of the ſenſe of ſight, we may form an experiment in order to know, how far the powers of giving viſion and of heating bodies, proceed equably, with the quantities of the ſolar ſubſtance, or with the meaſurable intenſity, in the different ſpecies of light. This, according to my experience, is far from being the caſe: The compound light, which is white, has a greater power of giving viſion, in proportion to its power of exciting heat; whereas, in the red ſpecies, it is the oppoſite; for, here the power of exciting heat is great, in proportion to its power of giving viſion.

This is the view of the ſubject which I have long entertained; it is a ſubject which I propoſe to examine more accurately, when I ſhall have a proper apparatus conſtructed. In the mean time, I may be allowed to reaſon upon that principle. I had no diffidence of the fact, at the time I made the experiment; but, at that time, I did not ſee all the importance of this principle. At preſent, again, when this fact comes to be of ſuch importance, in procuring explanation to a phenomenon which otherwiſe is anomalous, it would require to have experiments made with accuracy, and conceived with all the light of our improved knowledge.

We are not now inquiring for the cauſe of this diverſity of power, any more than of the different refrangibility of the ſeveral ſpecies of light; we are inquiring concerning a phyſical principle or a general truth, viz. If it be the conſtitution of light, to have one ſpecies more powerful in giving ſenſe, and another more powerful or diſpoſed for the dilating of bodies, *i. e.* for the exciting of heat.

With regard to the different refrangibility of the ſeveral ſpecies, no body doubts the fact; this is then a phyſical principle, no leſs general, perhaps, than that of gravitation, though not as yet ſo fruitful to philoſophy. The different powers of giving heat, I believe, is a matter of fact as certain as is the different refrangibilities, although not attended with ſuch a ſplendid phenomenon as that of the coloured ſpectre of the priſm. The evidence, in thoſe two caſes, is equal or ſimilar, although perhaps not ſo eaſily attained. In the one caſe, where the refrangibility is concerned, we judge by the ſenſe of colour, and by the perceived figure; in the other again, where the two ſpecies of light are to be compared with reſpect to the power of giving heat, it is by the ſenſe of feeling, and alſo by the perceived dilatation of the thermometrical fluid, that we are to judge. We cannot doubt of the different refrangibilities; becauſe, the ſenſible colour of the light correſponds with the changed direction of the rays; the proof is then immediate, and the chain of evidence compleat. It is otherwiſe with the power of giving heat; here two different ſpecies of light are to be compared, with regard to their power of giving heat, when they are of equal intenſity. In this caſe, a perſon may be allowed to doubt of the propoſition, ſo far as he may not have ſeen all the ſteps of the inveſtigation; it is even neceſſary, in ſcience, to withhold our belief until we trace the whole chain, and have ſeen the evidence of every ſtep.

The propoſition now under conſideration requires to compare different ſpecies of light, in equal degrees. Now, the means I employed to procure that equal degree of intenſity in the different ſpecies, was to reduce them, by diſtance from the luminary, to that degree of intenſity by which I was juſt enabled to read with the light. I thus could compare two different ſpecies of light in equal degrees, that is, the red light from a fire of coals, and the white light of flame. I then was able to eſtimate their heating capacities, compared with their power of giving viſion. I thus found the one ſpecies incomparably more powerful than the other, in exciting heat.

Let us now proceed upon that principle, for the explanation of natural appearances, particularly this of the irradiating influence of heated bodies.

A body, heated to the extreme of incandeſcence, gives out light in which the white or compound ſpecies prevails; but, as the intenſity of the heat diminiſhes, the light gradually becomes of the red ſpecies. Therefore, according to our principles, a body, in proportion as it is heated intenſely, radiates light which affects the ſenſe more, and heats bodies leſs; whereas, in proportion

tion as that heat of incandeſcence is diminiſhed, light is eradiated which affects the ſenſe of viſion little, and heats bodies much.

We have thus inveſtigated a certain rule with regard to the light, the heat, and the eradiation of ſolid bodies in certain degrees of heat. Our reaſoning was then founded upon thoſe events which take place in proceeding from the greater to the leaſt degree of incandeſcence; and now we want to proceed farther, after the irradiated light no more affects our ſenſe, which is a very indefinite termination. Here we are firſt to ſuppoſe that there is ſtill light irradiated, although our organ of ſight is not calculated to be ſenſibly affected by it. No body will refuſe to admit that ſuppoſition, who knows the great or indefinite capacity of the organ, in the ſenſe of viſion. To an eye which has been accuſtomed to the light of day, a place appears to be in perfect darkneſs, where, to another eye which has been long in darkneſs, objects become perfectly viſible.

Here is therefore a ſpecies of light which we may term *obſcure ;* and now the nature of this ſpecies of light is to be inquired after. But, in this caſe, the only concluſion to be formed is this, That the heating power of this *obſcure* light ſtill continues to diminiſh as it did before, that is, at a rate that is ſtill decreaſing ; for, we can only reaſon analogically, therefore muſt conclude, that the heating power of this irradiation, however decreaſing as the body cools, is always decreaſing leſs and leſs.

We are now come to this period in our ſcience of light, that if there be any ſpecies of the ſolar ſubſtance emitted by a body heated under the loweſt degree of incandeſcence, this emitted ſubſtance muſt be of that ſpecies which, although not viſible, is extremely much adapted for, or has great power in, the heating of bodies. Here then is a reaſonable conjecture, which, in order to be verified, and thus made a phyſical principle, would require to find that there is truly an emanation from the heated body, an emanation that may be reflected and concentrated in the manner of light, ſo as to have its power increaſed in a focus. But this is preciſely what in fact takes place, and this is the very appearance which we would now explain. A ſubſtance is radiated from a hot body; it paſſes with unmeaſurable ſwiftneſs through a tranſparent medium; is reflected from a mirror, and concentrated according to the laws of light, and then excites a degree of heat, in that focus, correſponding to its concentration,—here is a chain of action or efficiency that can apply to nothing elſe in nature, except to light. If this is not a demonſtration, it is at leaſt a proof in which there ſeems to be no defect.

The propoſition is this, Whether or not a hot body, after it has ceaſed to be incandeſcent, or to emit light viſible to our ſenſe, ſhall be conſidered as emitting light which may be effectual in exciting heat? The proof again conſiſts in this, firſt, that if any light be in this caſe emitted from the hot body, this ſpecies of light ſhould be as effectual in exciting heat, as it is ineffectual for the purpoſe of viſion; ſecondly, that it is contrary to the laws of nature, or inconſiſtent with our experience, that heat ſhould be tranſmitted any otherwiſe than from one body communicating immediately with another; and, laſtly, that the inviſible emanation from a hot body is actually irradiated, reflected, and concentrated in a focus where it excites heat. Therefore, if the nature of this ſpecies of light, which has been inveſtigated, ſhall be acknowledged, the phyſical propoſition will be demonſtrated, that is, proved without a ſhadow of doubt.

We have, in this manner, an explanation of that anomalous appearance, from which philoſophers have raſhly concluded, that heat is a thing which moves independent of bodies, and that this moving heat is a thing perfectly different from moving light.

Now this explanation is important to philoſophy, or the ſcience of cauſe and effect, ſo far as it tends to adjuſt our notions of light and heat, thoſe great agents which are ſo neceſſarily employed in giving us information by ſenſe, in communicating together the diſtant ſyſtems of luminating and illuminated bodies, and in actuating or enlivening the imperceptible parts of the ſyſtem of this world in which we are conceived to exiſt.

It muſt not be alledged, that light and heat are irradiated together, and that it is this irradiated heat which appears in the focus of the experiment, when there is no irradiated light: Philoſophers, indeed, have made that ſuppoſition; but this is only to ſubſtitute pure imagination in place of matter of fact, on which all phyſical ſcience muſt depend; and this is a view of the ſubject which cannot be too much reprobated if it is falſe, nor too much examined if it is doubtful. Let us therefore ſtate the caſe in a few words.

Light is radiated from bodies; and it moves through ſpace without the intervention of any other matter. Here is a phyſical truth, or principle, upon which we may ſafely reaſon; for, there is nothing in the compaſs of our knowledge by which that propoſition may be called into doubt. But, How are we to acquire a ſimilar principle with regard to heat? Not by analogy; for, Where is the analogy between light and heat? Light, heat, and electricity, appear all to be commutable, as different modifications of the ſolar ſubſtance; but, theſe three things are diſtinct, and muſt not be confounded. Heat is tranſlated among bodies in a certain manner, and electricity in another; but, neither of thoſe two different modes of tranſlation is the ſame with that of light; here then are three ſubſtances diſtinctly different in their moving ſtate. So far therefore as we reaſon analogically, we ſhould conclude that the tranſlation of heat, among bodies, is not performed according to the laws obſerved in that of light.

Conſequently, that there ſhould be ſuch a thing, as irradiated heat proceeding from bodies, is merely hypothetical, and cannot be admitted as a phyſical truth without ſome poſitive evidence, which as yet has not appeared.

Let us examine nature in relation to this ſubject, or that which is general in the action of heat and light. To move with the utmoſt velocity through the tranſparent ſubſtance of a body, without heating or affecting in any ſenſible degree that body which it traverſes, as is the caſe in the experiment which we have been conſidering, is a quality which does not belong at all to heat; but this is the very property of light. Heat is never tranſlated through a body without having been in action and reaction, or combination with its ſubſtance; but I have ſhown in another place, that light is not affected in its progreſſion by the gravitating matter of bodies; it therefore paſſes as freely through a tranſparent body as through the voideſt ſpace.

Hence it muſt appear, that to ſuppoſe heat moving in the manner of light, is no other than to confound the plaineſt principles in natural philoſophy. Let us now ſee how it may be with regard to the elective affections of this irradiated influence; for, if we ſhould find that this alſo correſponded with the elective affection of light, and not with that of heat, we ſhould thus obtain a confirmation of our theory, and a confutation of the oppoſite.

Here we have, in my opinion, no leſs than an *experimentum crucis;* for, if we ſhall find the affections of light and heat for bodies as diſtinctly different as are their laws of motion, and that the affection of this irradiated influence is that of light, then this inviſible ſubſtance, moving according to the laws of light, and having its elective affections ſimilar, could not in reaſon be miſunderſtood, but muſt be conſidered, in relation at leaſt to bodies, as light, although in relation to our ſenſe it may be inviſible.

But ſuch is the power of a ſyſtematic prepoſſeſſion, that M. Pictet, who has made this *experimentum crucis* with great preciſion, has entirely overlooked the important concluſion of this argument. I ſhall now give a view of that experiment.

In repeating M. de Sauſſure's experiment, M. Pictet conceived the deſign of trying what effect the colour of bodies might have, when expoſed to that influence which he conſidered as irradiated heat. For this purpoſe, he ſmoked the bulb of the thermometer to be placed in the converging focus of the experiment. He then found that the thermometer was heated ſooner, and roſe higher, by the concentrated influence, than when the bulb was bright.

Here is an evidence of the moſt convincing nature; for, while it homologates this irradiated ſubſtance or modification of matter with that of *light*, it alſo excludes it from being any ſpecies of heat. In order to ſee this, we have but to conſider, that here is a thermometer coated with a ſubſtance which admits or abſorbs light powerfully, but which tranſmits or conducts heat extremely ill, or ſlowly; conſequently, expoſed to the irradiated ſubſtance, the blackened thermometer ſhould be affected more or heated ſooner, if the irradiation from the warm body is light; whereas, if this irradiated influence is heat, the coated thermometer ſhould be heated ſlower. Thus, the experiment is deciſive; and the propoſition is fully proved, if we have reaſoned right.

Let us now ſee how far our reaſoning may be confirmed, from any other event which happens in this experiment. We have conſidered the effect in the thermometer, when this is expoſed to the heating influence of the irradiated ſubſtance, which thus is proved to be light; we are now to examine the effect of removing that irradiated influence, while the heated thermometer is expoſed to the cooling action of the ſurrounding atmoſphere.

According to the principle which has been employed to prove the propoſition, the coated body of the thermometer, though it be more quickly heated by the influence of light, yet, being once heated, it ſhould preſerve the excited heat from being ſo eaſily communicated to the atmoſphere which is in contact with the bulb of the thermometer. But, this happens preciſely in the experiment; the coated thermometer, which is heated ſooner than the bright one by the irradiated influence, when light is to be abſorbed by the coloured ſurface of a body, is cooled ſlower, when that acquired heat is to be communicated through the fuliginous coat, which is interpoſed between the thermometer and the atmoſphere. Thus our reaſoning is confirmed in being every way conſiſtent, and the experiment is deciſive.

But this reaſon, though concluſive in the theory of the inviſible ſpecies of light, would defeat its proper intention, if applied in ſupport of the theory of irradiated heat. For, if heat be ſooner or more eaſily communicated through a black ſubſtance than through a bright one, then ſhould the thermometer, when blackened, be cooled ſooner by communicating with the atmoſphere. In order, therefore, to reconcile that hypothetical theory of irradiated heat with the matter of fact, or that which appears in the experiment, it is neceſſary to make this abſurd ſuppoſition, that heat, in paſſing through the fuliginous coat to the thermometer, obſerves one rule; and, in paſſing through the ſame coat from the thermometer, it obſerves another. If this be not a contradiction in terms, it is the abſurdity of forming oppoſite concluſions from ſimilar premiſſes.

Names do not alter the nature of things; but when, in ſcience, we give the name of one thing to another which is different, we then confound our knowledge, and miſlead our underſtanding. How far that error has been committed, in this caſe of irradiated heat, will appear from the following conſideration.

The ſubſtance, which dilates the thermometer, is ſurely heat; and, when that ſubſtance quits the contracting thermometer, in order to dilate the contiguous atmoſphere, it is alſo heat, becauſe it then obſerves the laws of heat, and produces its effects. But, when a ſubſtance is irradiated from a warm body, when it traverſes with the velocity of light a tranſparent medium is reflected by one metallic ſpeculum to be again concentrated by another; and when it then heats a black body more eaſily than a bright one, we find a ſubſtance acting the part of light, in all reſpects, and not that of any ſpecies of heat; therefore, while this ſubſtance muſt be properly named *light*, it cannot, without abſurdity, *i. e.*

without committing a flagrant tranſgreſſion in our ſcience, be named *heat.*

Thus I have endeavoured to inveſtigate a new principle in the action of light; and I have applied this principle for the explanation of that apparently anomalous phenomenon of excited heat, in the experiment of M. de Sauſſure. I am now farther to employ our acquired principle; and to conſider an experiment of M. Pictet's, in which there is a ſtill more anomalous phenomenon, one which at firſt ſight ſeems to be inexplicable according to our theory, whether of light, or of heat and cold.

PART III.

A farther Application of the Principle of Inviſible Light to the Theory of Heat and Cold, with a view to explain M. Pictet's Experiment of Apparently Reflected Cold.

IN explaining the anomalous appearance, obſerved in concentrating the apparently irradiated and reflected heat of a warm body, the principles I have reaſoned from are theſe: Firſt, that light and heat are things commutable, under certain conditions, or in proper circumſtances. Secondly, that though light be the proper object of our ſight, this ſenſe is not always competent for determining the abſolute want of light; for, there may be indefinite degrees of light, as well as of heat, both above and below the proper feeling of our ſenſe. Laſtly, that there is, in light, ſpecies with different qualities and powers, and a gradation from thoſe which are moſt proper or much adapted for giving the ſenſe of light, and leſs adapted for the heating of bodies, to that ſpecies which, on the contrary, has great power in the heating of bodies, while it is but little adapted for the exciting of our ſenſe of ſight. Upon thoſe principles I have endeavoured to explain M. de Sauſſure's experiment, in which, I ſay, That there is inviſible light, but not obſcure heat according to his theory.

It may perhaps be thought, that this inviſible light, radiated from a large body that is dark, ſhould, by the concentration of the mirror, become viſible, by having its intenſity ſo much increaſed in the focus. But, had this been the caſe, there would not have been any occaſion for this diſſertation. We are here endeavouring to remove the apparent *anomalies* of the caſe; and this perhaps may be conſidered as one. We thus find ourſelves beſet with two oppoſite difficulties; for if, on the one hand, we ſuppoſe the thermometer heated by the reflected and concentrated light, Why ſhould not that light be rendered *viſible* by concentration? If, on the other hand, in order to remove that difficulty, we ſhould ſuppoſe, that the thing reflected is not light but heat, then, we would only extricate ourſelves from the dilemma by tranſgreſſing all the rules of light and heat. We are therefore poſitively excluded from this laſt ſuppoſition. Let us then examine the other ſuppoſition, viz. that of the inviſible light, which does not tranſgreſs any principle in our ſcience.

Light is a ſubſtance conſiſting of many different ſpecies, among which there would alſo appear to be an indefinite gradation; and, all thoſe different ſpecies are variouſly affected, in coming within the ſphere of action of gravitating bodies. We are now ſuppoſing a peculiar ſpecies, one that is inviſible, and one that is only known to us by its great aptitude for the heating of bodies. But, light cannot heat a body without entering into combination with its ſubſtance, or acting and reacting chymically in that body; therefore, here is a ſpecies of light which may be conſidered as having its want of viſibility ariſing from its great aptitude for combining with the ſubſtance of thoſe bodies into which it penetrates, inſtead of being reflected from their ſurface.

But the ſolar ſubſtance cannot both be reflected from a body as light, and at the ſame time be combined with it as heat; therefore, the ſpecies of light which we are now conſidering, ſo far as it has the diſpoſition for being combined in certain bodies, muſt be ſo far diſqualified for appearing as light. Thus we have reaſon to ſuppoſe, that, having once diſappeared to our ſight, this ſpecies of light will never be made to become viſible, by any degree of concentration, unleſs it were by heating the focal body to the degree of incandeſcence; in that caſe, it might be again emitted from the heated body as viſible light. There is, however, much room here for experiment, before the queſtion can be poſitively reſolved.

I have thus endeavoured to remove the objection, upon the ſuppoſition that this inviſible light cannot, by the moſt powerful concentration, be made again to appear as light in illuminating the body on which it falls. If this explanation of the ſuppoſed fact ſhall be thought inſufficient, we muſt ſuſpend our judgment, until experiment ſhall give more data for our reaſoning; for, we cannot be allowed to explain that phenomenon, by ſuppoſing that it is not light which is here concentrated by the mirror; ſuch a ſuppoſition would be the creating to ourſelves another heating ſubſtance, different from that which proceeds, as light, from the ſun and burning bodies.

Every arbitrary creation in our ſcience is improper; but here the theory of irradiated heat, beſides being an arbitrary ſuppoſition, will appear to be as unneceſſary or ſuperfluous, as it is evidently oppoſite to ſome of the moſt certain of our phyſical principles. If light and heat are mutually convertible, as from every other experiment there is reaſon to believe, there ſurely can be no occaſion to make heat be irradiated, reflected, and concentrated by a mirror, like light, in order to heat a body; for, by changing the modification of the ſolar ſubſtance, which is properly light, into that which in bodies is heat, a commutation which cannot be diſputed, this ſuppoſed anomalous appearance will be generaliſed with thoſe of bodies heated by the immediate influence of the ſun.

We have now acquired two principles, which may be employed in the farther progreſs of our ſcience.

Firſt, we have inveſtigated the nature of light and heat, ſo as to diſtinguiſh thoſe two things in all reſpects, and to underſtand what properly belongs to each. Here we have found, that light is not to be conſidered as having any power of giving either diſtenſion or fluidity to bodies; and that heat cannot be irradiated or move from bodies, as light does, either by reflection or tranſmiſſion.

Secondly, we have found that light, beſides being compoſed of different ſpecies with reſpect to colour, or the ſpecific effect known in the ſenſe, contains alſo ſpecies which have different powers, or powers of very different intenſities, both for the procuring of viſion and for the exciting of heat in bodies; and, that there is thus to be diſtinguiſhed a ſpecies of light which may be termed *inviſible*, as having little or no power of giving viſion, although it has a ſenſible effect in heating bodies.

By means of thoſe two principles, or that theory with regard to the powers of light,

M. de Sauſſure's experiment may be explained; and this I have endeavoured to do, in refuting the notion of reflected heat. I am now to conſider thoſe experiments of M. Mariotte, Lambert, and Scheele, already mentioned, when quoted by M. de Sauſſure.

In making thoſe experiments with regard to burning bodies, they conſidered heat as a ſubſtance eradiated from a fire; it then appeared to them, that heat was not tranſmitted through a body of glaſs, in the manner of light, but was arreſted in the glaſs, where it appeared with its proper effects as heat.

It muſt now be evident, that, if we have ſucceeded in eſtabliſhing the nature of heat, the notion of thoſe philoſophers muſt fall to the ground; for, if heat be not truly irradiated, in thoſe caſes of experiment, it muſt be the *light* of the fire which is arreſted in the glaſs, where it becomes heat;

therefore, while the body of glaſs is thus heated, the heating power of the radiated and tranſmitted light muſt be ſo far diminiſhed.

So far as the luminous power of light is leſs diminiſhed, by paſſing through the glaſs, than is its heating power, we thus acquire a new fact with regard to light, or a new principle in our ſcience, viz. that it is the inviſible ſpecies of light which is moſt abſorbed by the tranſparent body of glaſs through which the light is made to paſs. But this evidently appears from the well known experiment of kindling a combuſtible body, at the diſtance of many feet, by the reflection and concentration of the light from a burning coal, when placed between two concave mirrors; for, had the light of this burning coal been made to converge by paſſing through a lens, inſtead of being reflected by the mirror, the heat would hardly have been ſenſible in the focus, as appears from thoſe experiments of Lambert and Mariotte.

The heating power of fire light being thus ſuppoſed as being much more impaired, in paſſing through glaſs, than the luminous quality, this is not the caſe in being reflected by a metallic ſurface; for, the light of the fire, in being thus reflected, does not ſeem to have loſt its heating quality in any ſenſible degree. The only experiment that I have made upon this ſubject, is by comparing the effects of a glaſs mirror and a plate of tin, when employed to reflect the red light of a fire; the heat, in the caſe of the tin plate, is incomparably greater than in the other.

Thus we explain the phenomenon with regard to the light of fire; and thus we alſo acquire a new principle in the ſcience of phyſics, viz. that the heating ſpecies of light is much abſorbed in paſſing through glaſs, whereas it is but little affected in being reflected by metal.

But now we have a right to proceed ſtill farther upon our principles, and to ſay, That ſo far as there is ſomething irradiated, (whether light or heat,) and ſo far as this emanation concentrated in a focus gives ſenſible heat to a body in that place, upon no occaſion ſhould any cold appear to be produced in that focus. But this will require ſome diſcuſſion, in properly ſtating the caſe.

If by the emanation from a warm body in the one focus, and by the concentration of that irradiated ſubſtance in the other, ſenſible heat is excited, then, in diminiſhing that irradiated emanation, the excited heat will be diminiſhed, which is the ſame as growing colder. Now, when by the cooling of all theſe bodies they ſhall be in an equal temperature of heat, let us ſuppoſe the body, which had eradiated when warm, ſhall be cooled to a degree below the general temperature, or colder than the thermometer which is in the other focus, then here is a ſubject for our inquiry, viz.

If the thermometer ſhould be affected by the cold body in the other focus, any more than the other ſurrounding bodies. But, this ſubject cannot be properly underſtood, without conſidering the ſtate of bodies, with reſpect to emanation, when they are all in an equilibrium of heat.

In this caſe there naturally occurs a queſtion, viz. Do they then irradiate any of that emanation, which is capable of being reflected and concentrated?—Here is a queſtion which we are not informed of; conſequently, we know not if there be any emanation when there is an equilibrium of heat.

Thoſe philoſophers, who have adopted the theory of irradiated heat, do certainly ſuppoſe, that there is no irradiation when there is an equilibrium of heat among bodies, and that this only takes place, like the diffuſion of ſenſible heat, when the bodies are relatively hot and cold. But this is only a concluſion from their theory; and it is not, ſo far as I know, a matter of fact ſupported by any evidence; it is however a very material point in this ſcience, which therefore ſhould be aſcertained by experiment.

It will be no objection to this propoſed experiment to alledge, That, all thoſe bodies being in an equal temperature, and all irradiating equally the viſible light, there could be no cauſe for the diſturbance of that equilibrium, conſequently no means of knowing the fact. In this caſe, of a thermometer placed in the focus of one of the mirrors, there is certainly a diſturbing cauſe in relation to the equilibrium, whatever be the nature of the emanation; for, here the thermometer is receiving more than its natural ſhare of the irradiated ſubſtance, which we have found to be reflexible and concentrated by the mirrors. Therefore, in ſuppoſing heat irradiated, then, in properly diſpoſing things, the emanation from a large body in the one focus may be concentrated, ſo as to increaſe the temperature of a ſmall body in the other. But this muſt happen no leſs in the caſe of irradiated light, whether this be viſible or not. Therefore, here is a proper object for a ſcientific experiment; and, without making this experiment, the theory, of thus heating bodies by an inviſible emanation, is imperfect.

Let us now ſuppoſe that there is no emanation, in this caſe of bodies all in an equal temperature; and, let a cold body be placed in one of the *foci*, that is to ſay, a body much below the general temperature; What, in that caſe, ſhould be the effect obſervable in the focal thermometer?—It muſt be evident, that, upon our principles, the temperature of the thermometer, which the moment before was that of the general temperature, could not now be diminiſhed by the cold body in the other focus, no more at leaſt than if the two mirrors were removed; for, if there is no irradiation or emanation from the cold body, the mirrors can have no influence in relation to it, unleſs it were by bringing ſome irradiated matter from the other bodies, which are ſuppoſed to be all in an equilibrium of heat.

Now the queſtion is not, How far the general temperature of thoſe bodies will be diminiſhed, according to the laws of the diffuſion of heat, but, if the temperature of the body in the oppoſite focus ſhall be affected, according to the laws of reflected light, by any emanation or irradiation from the cold body, by means of the mirrors. Without attending properly to all thoſe circumſtances, the experiment muſt be imperfect; its information would be but a vague or unconnected event; and it might lead into the moſt erroneous concluſion.

What has led to this long diſcuſſion, is an experiment made by M. Pictet ſeemingly with great accuracy. It is that of placing a matraſs with ice in one of the *foci*, in M. de Sauſſure's experiment; he then found the thermometer in the other focus, which was of a warmer temperature, to be ſenſibly affected by it. This experiment was ſuggeſted by M. Bertrand, Profeſſor of Mathematics; and the reſult of it was a thing unlooked for by M. Pictet. But having found, contrary to his expectation, an apparent reflection of cold, he ſets about reconciling this appearance with his theory of reflected heat.

I ſhall now firſt give M. Pictet's explanation of the phenomenon, according to his theory; I ſhall then ſhow, that this explanation, which cannot be admitted upon the falſe principle of reflected heat, may be admitted upon the principle of inviſible light, provided that the ſuppoſition, which M. Pictet is obliged to make in his explanation, is juſt.

He proceeds upon this principle, although he does not expreſs it, that, in a chamber where all the bodies are in an equilibrium of heat, there is no irradiation; but that, as ſoon as there ſhall be introduced a body of a colder temperature, there will then be eſtabliſhed an irradiation of heat, from all the bodies of the chamber to the cold body, until the equilibrium be reſtored.

In applying this principle, he conſiders the thermometer as the radiating or warm body, and the matraſs with ſnow the cold body which is to receive the irradiated heat; and he employs the two concave mirrors, (placed at ten and a half feet diſtance), to convey the irradiated heat from the thermometer to the matraſs. This experiment he conſiders as the ſame with that of the matraſs with boiling water, only in this caſe of the ſnow the irradiated heat moves in the oppoſite direction, viz. from the thermometer to the matraſs; and this, he ſays, is a farther proof, were it neceſſary, of the reflection of heat.

We have acquired a new theory of inviſible light; and this theory may be now compared with that of the irradiated and reflected heat, in this explanation which M. Pictet has given, with regard to that anomalous phenomenon of an apparently irradiated cold.

That a ſubſtance eradiated in the focus of a concave mirror ſhould be reflected in parallel rays to another mirror of the ſame kind, and, by a ſecond reflection, be concentrated in the focus ſo as to be there collected in the very order in which it had proceeded, is conceivable; it is actually the caſe with light, and with no other ſubſtance ſo far as we know. Thus, we have here two focal centers that may be diſtinguiſhed, viz. the center of eradiation or emiſſion, and that of convergence or reception.

Let an irradiating body, ſuch as a candle, be placed in the one focus, and a white or refulgent body in the other; then, the white body will receive a great part of the irradiated light, and will reflect a great part of it again, while a certain portion of it will be retained in the modification of heat. But now, inſtead of the white body, let a black body be placed in the center of reception, then, more of the converging light will be abſorbed and become heat; but, we have no reaſon to believe that, in this caſe, any more light will proceed from the radiating center, than before. This is the caſe with *viſible* light; and, were we to reaſon analogically, with regard to the *inviſible* light, we would ſay, that a warm body, placed in the one center, would radiate its inviſible light at the ſame rate apparently, whether it were a warm or a cold body that ſhould be placed in the other center.

But though thus, in reaſoning analogically,

cally, we cannot ſuppoſe that a cold body, placed in the one center, ſhould have any influence upon the emiſſion of the inviſible light from the warm body placed in the other center, yet, ſo far as we do not know the laws that may be obſerved in the emiſſion of that inviſible light which has been now inveſtigated, or all the neceſſary conditions of its action and affection, we may conceive ſuch a thing; or, we might ſuppoſe it, without a manifeſt inconſiſtency with the laws of action proper to this ſpecies of light.

This however is not the caſe with regard to the explanation which M. Pictet has given of the phenomenon in his experiment; for, the ſuppoſitions which he is obliged to make are inconſiſtent with our phyſical principles. Firſt, he ſuppoſes heat to be radiated from the warm body in the manner of light, a ſuppoſition which is contrary to the rule of the diffuſion of heat, and the retention of that particular modification of the ſolar ſubſtance in bodies. Secondly, Socondly, he muſt ſuppoſe the irradiated heat to be reflected from the ſurface of the firſt mirror; here again is an idea contrary to our experience; for, inſtead of being reflected from the metallic body, if it is heat, it ſhould be moſt powerfully abſorbed by it. Thirdly, the irradiated heat muſt paſs by the cold body, be reflected again from the ſecond mirror, and be concentrated in a focus; and theſe are ſuppoſitions directly oppoſite to all that we have learned with regard to the laws of heat.

But this is not all, for, this explanation, which M. Pictet has given, requires another ſuppoſition to be made, a ſuppoſition analogous to what we have juſt now propoſed with regard to the emiſſion of inviſible light: This is, that the cold of the one body, in the center of reception, ſhall be a condition for the emiſſion of heat from the body in the center of eradiation, when otherwiſe that body would have emitted none.

I know not upon what principle this ſuppoſition, with regard to the emiſſion of heat from a body, ſhould be made; but now let us admit ſuch a ſuppoſition equally with regard to the emiſſion of inviſible light and that of reflexible heat, in order to ſee which of thoſe two theories will beſt explain the phenomenon, by means of the ſuppoſition which is here made.

With regard to the one, if we are ſatiſfied that it is not in the nature of heat to be eradiated from bodies, and to be reflected from a metallic ſpeculum, then, the new ſuppoſition, which M. Pictet is obliged to make in order to explain the appearance, muſt fall to the ground; for, where there is no emanation, there cannot be required any particular condition for that ſpecies of emiſſion. This however is not the caſe with regard to the other theory, which acknowledges radiated emiſſion of inviſible light; here we may be allowed to ſuppoſe certain conditions neceſſary for the emiſſion or not emiſſion of that irradiation; ſo far therefore as thoſe ſuppoſitions ſhall be found conformable to the natural appearances, there will be reaſon or probability in the theory; and then this theory may be admitted, not as a phyſical principle, (which it is not), but as a ground on which to proceed with other experiments, in order to be corrected if falſe, or, if true, to be confirmed, and thus become a principle.

I am now to propoſe an experiment of this kind; it is an experiment which M. Pictet might eaſily have made, or rather which he could hardly have failed to make, but to which he does not ſeem to have at all attended.

In the experiment we have deſcribed, there was apparently a radiated emanation of cold from a body; and this emanation appeared to be reflected from the ſurface of a metallic ſpeculum in the manner of light, and to be concentrated in a focus, by which

a

a body was cooled. M. Pictet, who, like other natural philoſophers, cannot allow the poſitive nature of cold, has attempted to explain the appearance, by ſuppoſing an emanation of heat, from the thermometer in the one focus, and the abſorption of that heat, by the cold body in the other focus, after it has been twice reflected from the mirrors. I have now endeavoured to ſhow the error of that explanation; and I have propoſed an explanation of the ſame kind, upon the principle of inviſible but heating light. In this explanation there are required certain conditions for either the emiſſion or not emiſſion of that light from bodies; which conditions we are at preſent obliged to ſuppoſe, not from any principle in our ſcience, but merely for the purpoſe of that explanation.

But now, in order to acquire ſome more light into this doubtful ſubject, it would be neceſſary to inquire concerning the particular direction in which the radiated emanation is made. We have been conſidering this emanation as proceeding from the thermometer, and as terminating in the cold body, which is the condition for the emiſſion or emanation of that ſubſtance which, while in the body, is the cauſe of heat. This then is a matter of fact, which it is of the utmoſt importance to have decided, before we proceed any farther in reaſoning upon appearances with regard to the nature of heat and cold. Now, this is what I think we have the means of doing; and this is what I am ſurpriſed that M. Pictet did not inquire into, inſtead of giving us a hypothetical explanation of a dubious or equivocal appearance. I ſhall now deſcribe this experiment.

In this caſe, of the apparent irradiation of cold, we have an extremely ſmall body, *i. e.* the thermometer, in the one focus, and a great body, *i. e.* the cold matraſs, in the other. Therefore, if the emanation proceeds from the great body, the ſmall body will be affected, by the concentrated emanation, when it is in that focal place; but, remove it never ſo little out of that place, to the one ſide, and it will not be any more affected by the concentrated emanation. If, on the contrary, the emanation proceeds from the ſmall body, then, altho' this thermometer be removed to a ſide juſt out of the focus, ſtill the emanation from it will fall upon the large body, although not upon the middle of it; conſequently, that cold body ſhould ſtill have the ſame effect upon the thermometer, as affording to it the proper condition for the emanation of its heat in the form of light.

If it ſhould thus be found, that the irradiated matter does not proceed from the thermometer, to the cold matraſs as the proper condition for its emanation, this would be at leaſt one ſtep gained; and, this might lead us, or be the means of directing our farther progreſs in this phyſical reſearch.

I have been now propoſing a certain explanation with regard to the phenomenon of the experiment, in reaſoning after the manner of M. Pictet; but, this was only in order to compare the theory of reflected heat with that of the inviſible light of bodies, when theſe two theories ſhould be ſeverally employed for the explanation of appearances; and, it was not with any view of affording ſuch a ſatisfactory evidence as phyſical truths require. So far from having had that view, I am now to ſtate a ſerious objection, in my opinion, to this manner of explaining the phenomenon, whether according to the theory of irradiated and reflected heat, or to that which I have propoſed according to the theory of inviſible light.

When a quantity of heat or light is ſuppoſed to be irradiated in the one focus of the two oppoſite mirrors, and when this irradiated ſubſtance is collected by the reflection of thoſe mirrors into the other focus, it muſt be eaſy to conceive how that irradiated ſubſtance may be greatly increaſed in its intenſity by this concentration, and thus either illuminate or heat a ſmall body in that focus; but, when we ſuppoſe a ſmall body radiating in the one focus, and a comparatively great body attracting or receiving that irradiation, in the other, as is the caſe at preſent in ſuppoſition, Why is not the thermometer, which is the ſmall body, quickly reduced to the temperature or degree of cold which is then ſubſiſting in the great body? Nothing like this, however, actually takes place; for, the thermometer, which is of air, and contains only a grain or two of matter, becomes ſtationary when there is a vaſt diſproportion between the degrees of heat in thoſe two bodies.

Here is a difficulty which occurs to the explanation of the phenomenon, whether we ſhall ſuppoſe that irradiated matter to be either heat or cold, and whether that emanation proceeds in the one direction or the other; for, if a free communication is eſtabliſhed, by means of the mirrors, between the cold and hot bodies, as there would be by immediate contact, Why is the temperature of the thermometer ſo extremely little affected? The reſpective temperatures of thoſe two bodies are not to be conſidered as any ways communicated; for, 30 or 40 degrees of cold in the matraſs does not produce above one half or one fourth of a degree in the thermometer; and this is done almoſt immediately, after which the thermometer becomes ſtationary. I mention this as an appearance in ſome degree inconſiſtent with the ſuppoſition of it being either heat or cold that is here communicated; for, were the temperatures of bodies thus communicated, Why ſhould that extreme ſmall body, of the thermometer, make no farther approach towards the temperature of the matraſs, while this cold body, which had ſo ſuddenly affected the thermometer, is nothing ſenſibly diminiſhed in its power of either taking heat or giving cold?

Having thus found the greateſt, if not the moſt inſurmountable difficulty in explaining the phenomenon in queſtion, by ſuppoſing bodies not eradiating inviſible light when they are all in an equal temperature of heat, we may now examine what may be the effect of ſuppoſing, on the contrary, that bodies, in that caſe of equal temperature, are always emitting inviſible light proportionably to their ſenſible heat.

I have already ſhown, that if bodies truly radiate either inviſible light or reflexible heat, when in an equal temperature, this may be rendered ſenſible in its effects, by means of the concentrating mirrors. We are now to conſider how far M. Pictet's experiment, of an apparent emanation of cold, may find any explanation in the ſuppoſition which we are now to make, viz. that, in an equal temperature of heat, bodies are always radiating their inviſible light. But, let us firſt endeavour to form ſome diſtinct notion with regard to that particular ſtate or conſtitution of things, which analogically we have every reaſon to ſuppoſe.

We have found that bodies, far below the heat of incandeſcence, eradiate a ſpecies of light, which is reflexible by metallic ſurfaces, and which has great power in exciting heat. We know not any period, in the gradation of cold, at which this irradiation ceaſes to be emitted from bodies; for, as it is only by the reflection and concentration of this inviſible light that we become ſenſible of its exiſtence, by the heat which it produces, we have no reaſon to doubt of its exiſting long after it ceaſes to be the object of our obſervation. In order to underſtand this, let us conſider the natural ſtate, in relation to heat as well as light, of thoſe bodies from whence we have our information.

We are to contemplate bodies communicating mutually their irradiated light; by this means, their temperatures with regard to heat muſt be always changing, and always tending to be equaliſed. But, there is another cauſe always acting, in tending to form an equilibrium of heat among bodies; for, thoſe which are in contact, communicate their heat by the act of diffuſion: Thus, by means of the earth on which they reſt, and the fluid medium in which they are involved, bodies muſt be conſidered as always communicating their temperatures, and the warmer giving heat always to the colder, particularly by means of the fluid medium in which they are immerſed.

There are thus two ſources for the communicating of heat among bodies; and, each of theſe two modes obſerves its proper laws and conditions of action and affection. To illuſtrate this, the obſcure or inviſible light, which is ſo powerful in communicating heat, appears to be very differently affected, in meeting, on the one hand, with a tranſparent plate of glaſs, and on the other with the refulgent ſurface of a metal; in the one caſe, it is powerfully abſorbed or converted into heat; in the other, it is powerfully reflected, and therefore ſhows little effect in heating the metallic body. Such are the laws obſerved in the various abſorption and reflection of light; by which means different bodies are variouſly affected in their temperature, though all equally expoſed to the ſame irradiated light.

In like manner the diffuſion of heat proceeds alſo upon very different principles, in which, however, we find a ſort of general rule, which is obſerved in a great degree. But, fluids poſſeſs a peculiar property in relation to the communicating of heat among bodies; for, being much dilated by the heat which they receive, and being moved, by that dilatation, in relation to the body from whence they had received heat, they acquire a new power of mechanically tranſlating heat, by conſtantly applying cold parts to the warmer bodies, and warm parts to the colder.

Light and heat being thus active principles in relation to bodies; and, natural bodies being ſo differently affected by thoſe active principles, this exhibits a very complex ſtate of things, in which the various aſſociated bodies are to be conſidered as mutually acting and affected, whenever any of them has a different temperature from the reſt. But, before conſidering bodies in that ſtate of different temperature, we are firſt to ſuppoſe them all to be of one temperature, or in an equilibrium with regard to heat, but all irradiating their inviſible light.

We ſhall now eaſily perceive, that the ſuppoſed ſtate of a perfect equilibrium, or equal temperature among bodies, is, like that of their conceived equalities, a thing merely ideal; and that, ſuppoſing it actual, it could not ſubſiſt a moment. It is in ſuppoſition,

poſition, that the bodies are all eradiating inviſible or heating light; it is alſo certain, from experience, that this light is variouſly affected, according to the colour, the refulgence, the tranſparency, and other ſpecific qualities of the bodies on which it falls, through which it is tranſmitted, and by which it is reflected. Here, therefore, is a continual ſource of variation, or change, for the heat of bodies. But, as bodies emit inviſible light only in proportion to their ſenſible heat, we find, in this, an oppoſite ſource of equalization, tending to reſtore that equilibrium which is alſo continually loſt. Things therefore are not kept in any ſtate of inactivity, when we perceive no change; but, they are often preſerved apparently ſtationary, when there is truly nothing fixed, and when oppoſite powers are alternately prevailing, or continually balancing each other.

Theſe are the general principles upon which our ſcience, with regard to the changing temperatures of bodies, muſt proceed. Let us now conſider the particular ſtate of things, in that experiment which is the ſubject of our reaſoning.

The thermometer, which is the body to be either heated or cooled in the focus of one of the mirrors, is an air thermometer: the bulb is only three or four lines in diameter, and blown as thin as poſſible. This body is therefore affected by a very ſmall quantity of heat; and, it is expoſed with ſo great a ſurface to the ſurrounding fluid medium, that it muſt be quickly reduced to the temperature of the atmoſphere by the diffuſion or communication of its heat.

It is in this ſtate that we are to conſider the indicating thermometer in our experiment. Being placed in the focus of a reflecting ſpeculum, great part of the light, which falls in a proper direction upon that ſpeculum, is concentrated in the focus, ſo as to increaſe the heat of the thermometer;

and the circumambient air is continually abſtracting that increaſed heat. This body therefore, in theſe circumſtances, may be continually receiving heat by means of irradition, and continually emitting heat by diffuſion, while, from our obſervation, we might conclude that it is ſtationary, and that it is neither receiving nor emitting any thing, if the quantity of change is ſufficiently ſmall, or if the means of our information are not ſufficiently accurate.

We are conſidering this extremely ſenſible thermometer placed in the focus of one of the mirrors, while there is nothing in the focus of the other, and when all the ſurrounding bodies are ſuppoſed to be of the ſame temperature. In this caſe, we muſt ſuppoſe that the temperature of the thermometer will be increaſed, although, from the ſmall quantity of that increaſe, and from the operation of the air preventing any farther accumulation of heat, that degree of increaſed heat may be too ſmall to be a matter of obſervation. Let now a maſſy body, ſuch as a matraſs with water, of the ſame temperature with the ſurrounding bodies, be placed in the other focus. Here is evidently, upon the principle now in ſuppoſition, *i. e.* of bodies always emitting inviſible light, a cauſe for a farther increaſe of the heat of the thermometer, although this perhaps may ſtill be too ſmall an object for our obſervation unleſs executed with art. But, this is a fact of which we are not at preſent informed ; it is a fact of which M. Pictet certainly had the opportunity of informing himſelf, had he taken this view of the ſubject ; and it is the fact, perhaps, upon which the explanation of his experiment, with regard to cold, depends.

In order to ſee this, let us ſuppoſe that the thermometer ſhall be actually half a degree warmer than the temperature of the ſurrounding bodies * ; then, inſtead of the matraſs being of the common temperature of the place, let one full of ſnow be placed, as M. Pictet did, in this experiment. It muſt be evident that, in this caſe, the heat of the thermometer muſt be diminiſhed; not by the reflection and concentration of any cold emanation from the matraſs, but by a ſmaller irradiation of that emanation by which the thermometer had been heated before. Take then away the cold matraſs, and the thermometer will riſe in its temperature; increaſe the cold of the matraſs, as M. Pictet did, by the effuſion of nitrous acid, and the thermometer will ſink in its temperature.

---

* To thoſe who know how difficult it is to aſcertain the temperatures, in caſes of change, this ſuppoſition will not appear to be unreaſonable.

The general philoſophic view of the ſubject, which I would now propoſe, is this; Firſt, that when we have a thermometer placed in the focus of a concave ſpeculum, the rays, which in general come from the oppoſite ſide, are concentrated by the reflection of the mirror, and thus made to heat that thermometer above the common temperature of the place. Secondly, when we have a great cooling cauſe introduced into that ſide from whence the inviſible light had been radiated to the mirror, the heat acquired by the concentration, whatever that may be, muſt be diminiſhed. Hence the thermometer will be affected apparently by the irradiation of cold, when truly it is only affected by the irradiation of a ſmaller quantity of the inviſible heating light.

This experiment is not a ſubject for common obſervation. The differences of temperature, to be obſerved, are neceſſarily ſmall; and therefore the inſtruments require to be made extremely ſenſible. But, not only are accurate inſtruments required, it is alſo neceſſary to make the obſervations with proper ſkill and minute attention to every affecting circumſtance; otherwiſe, the experiment, inſtead of advancing ſcience, might miſlead our underſtanding of the ſubject. I make no doubt that, in the hands of M. Pictet, the problem may be eaſily reſolved, whenever he ſhall make the experiment with that view. But, in thoſe experiments, where minute changes are the ſubject of obſervation, and where the quantity to be meaſured approaches ſo nearly to the neceſſary errors of obſervation; although the reſult may be ſufficiently ſatisfactory, the accuracy of the experiment would require all the poſſible means of confirmation.

The experiment which M. Pictet has given us has every mark of ability in the deſign, and accuracy in the execution; but it was not made with the view which I have here propoſed. It ſhowed ſufficiently all that was required, viz. that the cold body in the one focus had a manifeſt effect upon the thermometer in the other; but no obſervation could be made for aſcertaining the point now in queſtion, which was not then probably a ſubject of conſideration. This experiment, therefore, is far from being deciſive of the important queſtion, however well it is adapted for raiſing doubt with regard to the theory of heat and cold. I have now endeavoured to remove that doubt, and to give an explanation of the appearances in that experiment, by reaſoning from our acquired principle of inviſible light. But, this explanation is conditional; and, in order to its being made abſolute or confirmed, it would require the accurate obſervation of many circumſtances. I do not therefore give it as deciding the queſtion with regard to the nature of heat and cold, but as leading to thoſe obſervations and experiment by which it is to be decided.

In conſidering the former explanation, which proceeded upon the ſuppoſition that the different temperatures of bodies was the proper condition for the emanation of either light or heat, I made an objection to thoſe explanations, in that the effect appeared to be ſo much diſproportioned to the cauſe. This objection, however, of too ſmall a quantity in the effect, will not naturally occur in the explanation which has now been given; but, how far, on the other hand, this quantity may be conſidered as a thing too great, therefore likewiſe diſproportioned to the cauſe; is what I have not proper data to decide.

I am ſuppoſing that there was a difference between the thermometer and the general temperature, before the cold body was applied; but not knowing what this difference is, it is impoſſible to judge of the proportion in the effect. Let us ſuppoſe that the temperature of the thermometer is increaſed, by means of the mirrors, a degree or half a degree above what it would otherwiſe indicate, and that the half, or the quarter of that influence, ſhould be loſt by the introduction of the cold matraſs, we ſhould then have reaſon to ſay, that the effect did not ſeem to be diſproportioned to the cauſe. But, were we thus to have an effect correſponding to the cauſe in quality, and alſo juſtly proportioned in its quantity, we ſhould have an explanation of the phenomena, in which there would be no apparent error or defect.

But now it will be proper to take a view of thoſe deficiencies, in our phyſical ſcience, which muſt retard the progreſs of philoſophy; it is by ſeeing ſuch defect that we may proceed, by reaſon and experiment, to remove the obſtructions in our knowledge. In no ſubject, perhaps, of natural philoſophy, is there ſo fertile a field as in that of light and heat; in no ſubject, therefore, is it more important to call the attention of philoſophers.

PART IV.

An Examination of the preſent ſtate of Science reſpecting Light, Heat, and Cold; with a view to promote the Philoſophy of that ſubject.

WE have been examining certain anomalous appearances with regard to the effects of heat and cold; and we have conſidered the explanation of thoſe appearances by men of ſcience who had made the experiments. Now, I have ſhown that theſe explanations are not conſiſtent with the phyſical principles generally received; and I have endeavoured to reconcile thoſe appearances with our principles, by taking the ſubject in a different view, and by inveſtigating more particularly the nature of light in relation to its power of exciting heat.

Having thus compared two different phyſical theories, I then propoſed certain experiments by which theſe hypothetical explanations may be tried. If the principles upon which we have been reaſoning in explaining thoſe anomalous appearances ſhould be thus confirmed, we would then have made an acquiſition of ſome new principles for the farther progreſs of our ſcience.

The immediate object of that inveſtigation, which has now been given, reſpects the apparent reflexibility of heat and emanation of cold, events which certainly require to be ſtrictly examined. But, in the mean time, before thoſe queſtions are finally decided by experiment, it may be proper to ſee the importance of the ſubject to natural philoſophy, and alſo to ſee the neceſſity of that accuracy in making ſcientific analyſis, by which it may be qualified to anſwer the end of its intention. In that caſe, the ſcience of phyſics may appear to be no leſs perfect in its nature than is that of mathematics, which is a light in which that ſubject is not commonly viewed.

For this purpoſe, I wiſh to call the attention of philoſophers to the general ſcience of which we have here a particular ſubject under conſideration. For, if the progreſs of philoſophy may be retarded by a certain error in the manner of purſuing ſcience, or by an inadvertency which needs only to be ſeen to be corrected, here is the moſt important ſubject for inveſtigation,—to point out the place where the true path of ſcience had been forſaken. Here is an object of which we never ſhould loſe ſight, viz. to examine carefully the truth of every ſtep by which we had proceeded in our ſcience; as one falſe ſtep may lead into the moſt inconſequential train of reaſoning, and vitiate the philoſophy in which that ſcience is employed.

We can only judge of the ſtate of ſcience, in any branch, from the opinions of philoſophers who have written upon the ſubject. I have therefore given what has been ſaid by eminent men of ſcience, with regard to heat as a philoſophical principle. Having thus the opinion of philoſophers reſpecting heat in general, and having ſeen their application of that phyſical theory for the explanation of phenomena in thoſe intereſting experiments which we have now examined, we thus procure data for judging of the general ſtate of knowledge in that branch of ſcience—a branch which is not only uſeful in itſelf, but is at preſent that with which natural philoſophy is perhaps the moſt concerned.

From ſuch a view of things as this, I perſuade myſelf that the ſubjects heat and cold, as qualities of bodies, or principles of action in external things, will ſoon attract the attention of philoſophers, who muſt inquire into the cauſe of every *change*, as well as into the nature of every *ſtate* of things. There is alſo reaſon to believe that this ſubject heat and cold, when properly analyſed, or traced to the firſt principle, and when all the ſteps of that inveſtigation ſhall be clearly perceived, will appear to be the moſt important principle in natural philoſophy, after that of gravitation. This quality of bodies, which we term heat, muſt therefore appear to merit all the attention that we can beſtow; for, if natural philoſophy has made ſuch progreſs by the ſucceſsful analyſis and generaliſation of another quality, namely, that of weight, there muſt be every reaſon for proceeding in a ſimilar manner with the quality of heat;—a quality no leſs inherent in bodies than is that of their weight, and a quality certainly no leſs powerful in its effect.

We have been endeavouring to explain a certain appearance with regard to heat; but the explanation of a particular appearance, however important in the ſcience of phyſics, is an inferior object in the view of natural philoſophy; for, here the proper object is to make men of ſcience attend to the inveſtigation of thoſe principles by which appearances in general are to be explained. It is chiefly with the view of making it uſeful in philoſophy, that I have now examined the ſubject heat and cold, in thoſe particular experiments, and in the explanation given by philoſophers of thoſe appearances. It is now time to aboliſh that inconſequent manner of reaſoning, with regard to natural philoſophy, which has been practiſed in the dark ages of phyſical ſcience.

We have at leaſt one great principle from whence to reaſon in purſuing ſcience; and, what is ſtill more, we underſtand the ſcience of reaſoning by means of phyſical principles: This is the ſubject to which I now mean to call the attention of philoſophers, in ſeeing thoſe obſtructing cauſes which are to be removed, and in thus pointing out the proper means to be employed in bringing our preſent ſcience to a more perfect ſtate.

At one time, the abhorrence of a vacuum was thought to explain the particular appearance for which that notion was conceived; at preſent, a natural philoſopher would be aſhamed to entertain ſuch an idea. But though our mechanical philoſophy, in reaſoning from ſound principles, is ſo much improved, there is reaſon to believe that natural philoſophy is not equally fortunate in other branches of our ſcience. Natural philoſophers, even the moſt enlightened men, have now propoſed to explain a certain appearance upon a principle perhaps no leſs unſcientifically conceived; this is that of reflected heat. Here is a ſubject which demands the ſtricteſt examination; not only with a view to correct one falſe ſtep which has been made, but to prevent any farther deviation.

In order to explain a matter of fact, or natural appearance, by a matter of hypotheſis, there muſt be ſome *media* by which the thing to be explained, and the hypothetical invention, may be properly aſſimilated; and the medium, thus employed, muſt be a matter of fact, or an acknowledged truth. But, the reflection of heat, which is the hypotheſis in the explanation, is, like the abhorrence of a vacuum, a mere ſuppoſition, and has no evidence in nature, although, like the other, it is conceived in idea and expreſſed in language; it is an incongruous aſſociation of ideas which have no natural relation. But, philoſophy muſt ſee the evidence of every ſtep, or mean employed between the explanation and the appearance; it muſt alſo ſee the ultimate or firſt principle from whence all the others muſt derive their evidence; and, it muſt ſee thoſe principles which, while they are neceſſarily believed, cannot be farther explained in ſeeing their principle: It is *then* that philoſophy is perfect in any ſubject.

It may perhaps be alledged, that inviſible light, by which I have endeavoured to explain the appearances in thoſe experiments, is nothing but another term for that which has been called obſcure or reflected heat; and, therefore, that the term *reflected heat* muſt give the ſame idea as that which is to be annexed to *inviſible light*, *i. e.* matter moving from one place or body to another. This argument may, to ſome, appear ſpecious; therefore it ſhall now be anſwered.

There is an infinite difference between the idea of reflected heat, and that of inviſible light, ſo far as heat and light are things abſolutely different; and though reflexibility might ſo far aſſimilate heat with viſible, and ſtill more ſo with inviſible, light, this can have no influence on the preſent queſtion, which is not, Whether reflexible heat might explain the appearance; but, Whether there be ſuch a thing as heat that is reflexible? With regard again to the queſtion, Whether there be ſuch a thing as inviſible light? this is at leaſt a rational ſuppoſition; for, though viſibility be an attribute of light, this is only in relation to our ſenſe; whereas, in relation to bodies, light has other attributes; it moves with a certain velocity, and it is either reflected, abſorbed, or tranſmitted, according to rules and conditions which are to be inveſtigated. Beſides, with regard to its viſibility, there is an indefinite gradation from the brighteſt to the moſt obſcure light; and we have every reaſon to believe, that light continues to be radiated from bodies after it ceaſes to be viſible to our ſight, in like manner as there is heat in bodies which to us appear cold. But, to ſuppoſe heat moving from a body in the manner of light, and to be concentrated by a reflecting ſpeculum into a focus, is a propoſition that is unreaſonable, as being founded upon no real idea or actual knowledge. It muſt not be alledged, that it is founded upon this experiment or fact which is to be explained by it; we might as well ſay, that the abhorrence of a vacuum is proved by the riſing of water in the pump. Before reflexible heat can be employed for the explanation of the experiment,

riment, there muſt be ſome reaſon given for this fact in ſuppoſition, viz. that heat is reflexible; and, at preſent, there are none, ſo far as I know.

I have been repreſenting the theory of heat and cold as the ſecond great principle in natural philoſophy; I wish the evidence of that propoſition to be ſeen; and now I ſhall endeavour to ſhow the great importance of it.

Weight has been generaliſed, and thus is found to be an inherent quality in every body. Here then is a general principle of action in bodies, of which we underſtand the meaſure and conditions. But, is the heat, or is the cold of bodies, a principle or a fact of leſs importance in the ſyſtem of this world, than is that of their weight? Now, all I contend for is this, that philoſophers ſhould ſeek for that principle in the heat and cold of bodies, which cannot admit of any farther explanation, and which muſt have its truth as evident, to thoſe who ſee the ſteps of the inveſtigation, as is that of gravitation, which is the firſt, I had almoſt ſaid, the only general principle at preſent acknowledged in natural philoſophy; for, Have we any univerſal principle of natural bodies, except that of their gravitation? and, Will the principle of gravitation explain all the qualities of natural bodies, and all their accidents and events, which it is the province of natural philoſophy to do? So far from this being the caſe, that there are perhaps as many appearances inconſiſtent with the principle of gravitation as a cauſe, as there are of thoſe which may be explained by it. It is needleſs, on this occaſion, to exemplify in the violent exploſion of gun-powder from the ſmalleſt ſpark, the gentleſt expanſion of a body proves the propoſition.

In treating of heat, (vide Diſſertations upon ſubjects of Natural Philoſophy), I have endeavoured to inveſtigate the principle of action by which are to be explained certain appearances in bodies, in like manner as has been done to the ſatisfaction of philoſophers with regard to weight; what may be the opinion of philoſophers, with regard to that inveſtigation, has not yet appeared; I therefore cannot reaſon upon that principle, as being admitted in our philoſophy, which is the caſe with reſpect to gravitation. In the mean time, let us compare the progreſs of ſcience with regard to thoſe two principles, weight and heat.

That bodies were known to be heavy, before the firſt bright period of natural philoſophy, is certain; the common ſenſe of mankind had generaliſed bodies according to that quality, of tending to deſcend with power; but they did not know the principle upon which that quality of weight depended, in ſeeing the more general rule for the direction and intenſity of that action. The caſe is ſimilar with regard to the qualities of heat and cold; mankind have always generaliſed theſe actions or paſſions more or leſs in ſeeing the order of theſe events. But it is not enough to ſee that heat expands bodies; we muſt ſee the principle on which depends the expanding power, heat, or the conditions in which it acts; and, we muſt know the law which is obſerved in the direction and intenſity of that action. Here then would be the general principle of heat; thus we ſhould have another great power in bodies, with which that of gravitation might be compared; and we ſhould have another general principle by which the phenomena of nature might be occaſionally predicted, as well as generally explained.

Before the time when the rules of the great Bacon began to be obſerved, philoſophers generaliſed matters of fact or vulgar notions, without analyſing them in order to find thoſe principles in which they may agree, or by which the various appearances of nature are to be explained; experiments were then deficient, and philoſophers, in generaliſing cauſes or events, were obliged to aſſimilate things upon fallacious grounds. But what excuſe can be given for philoſophers, in this age of analytical ſcience and experiment, aſſimilating things which are the moſt diſtinctly different? In like manner, What is the reaſon why philoſophers have not generaliſed ſubjects for which they have ſufficient data in their ſcience? Here, it is evident, there muſt be ſome defect; and, to ſee the reaſon of this defect is at preſent the ſubject of conſideration.

Natural philoſophy is founded on experiment; but, though the uſe of experiment is at preſent well known, the ſcience of that art is not equally underſtood. In order, therefore, to underſtand that practice on which the progreſs of natural philoſophy depends, we may now conſider the diſtinction of experience and experiment, as the means of knowledge.

In the perception of natural events, a philoſophic mind judges a certain order in the ſucceſſion of thoſe things, and a certain ſimilarity in the things which are diſtinguiſhed. This conceived order, then, is the ground on which proceeds the diſtinction of cauſe and effect, the proper ſubject of philoſophy. But, this is a progreſs of underſtanding beyond what falls to the ſhare of the mere animal mind, which nevertheleſs reaſons by experience, as well as the philoſopher. There is, however, this great difference, between the reaſoning of the brute mind knowing from experience, and that of man conceiving order in that which he perceives; the brute reaſon is not ſubject to error as is that of the philoſopher; and, in reaſoning ſcientifically, we find the diſtinction of true and falſe, which does not take place in the reaſoning of the animal.

Man having thus formed a ſyſtematic order in the ſucceſſion of events, true philoſophy is the placing of effects in the order of their cauſes, as falſe philoſophy is the miſplacing of thoſe things. With regard to phyſical knowledge, therefore, experience is the ſagacious obſervation of ſimilarity among diſtinguiſhed things, which happen in external events; but, experiment is more than this experience. Experiment is the wiſe deſign of a ſcientific mind, inquiring after the order of events, and thus ſeeking knowledge by which it is to be made ſtill more wiſe.

Having made this diſtinction, we may now perceive, that the making of experiments without a wiſe deſign is the one extreme, in which a philoſophic mind may wander; and that the placing of events in the order of cauſe and effect, or the generaliſing of them without proper evidence, is the other extreme. But, not to generaliſe thoſe events, when we have the means in our ſcience, is ſurely a defect, as is likewiſe the neglecting to make thoſe experiments to which we are directed in our ſcience,—experiments for diſcovering the true order of events, that is to ſay, for making progreſs in our philoſophic knowledge.

That natural philoſophy muſt proceed upon matter of fact, as its fundamental principle, is certain; but matter of fact and philoſophical experiment muſt be diſtinguiſhed. Phyſical ſcience proceeds immediately upon matter of fact; but, philoſophical experiment proceeds upon theory, or thoſe generaliſed phyſical and mathematical truths which are the produce of our ſcience. Therefore, without a juſt progreſs in our philoſophy, our phyſical experiments, made without a general deſign, never can immediately advance philoſophy, however they may become uſeful in being generaliſed by the ſcience to which they properly belong. Science conſiſts in properly generaliſing truths; but, philoſophy muſt proceed in generaliſing thoſe truths which are the object of particular ſciences. This may be illuſtrated.

That all bodies fall equal ſpaces in equal times, is a generaliſation in our ſcience; and it is a proper ſtep on which to proceed for generaliſing all thoſe events in relation to the fall of bodies, in order to ſee the general principle of action which is gravitation. But, gravitation is a general principle for acquiring ſtill more knowledge, or it is a principle for acquiring ſtill more general knowledge of the nature of things. Now, philoſophy is that general knowledge by which the works of nature are underſtood in ſeeing the wiſdom of deſign; it is *then* that we become wiſe in knowing cauſes, and in foreſeeing events; and, *this* is properly philoſophy. By ſuch philoſophy we may be led to find the wiſdom of deſign, in thoſe things which are around us, and with which we are neceſſarily concerned. But, by erroneous or falſe philoſophy, we only feign to ourſelves a ſyſtem as we do a dream, and do not ſee the intention of our Author in the works of nature, which is the proper object for the human underſtanding. It is only thus that man is raiſed above the ſenſitive and perceptive being which he is firſt, before he diſtinguiſhes and generaliſes, in knowing truth and falſehood, good and evil.

That there is ſomething defective in our natural philoſophy will appear from this; philoſophers, in the firſt great progreſs of our ſcience, have explained certain appearances upon the principle of a general attraction among bodies; but now, in this enlightened age, other philoſophers pretend to explain the ſame appearances, and more, upon the principle of a general repulſion. Were the phenomena of nature to be explained by a ſingle principle of action, it might be a very ſerious queſtion, whether that of attraction or repulſion were to be admitted as the univerſal principle? But, why narrow the field of philoſophical inveſtigation, by limiting nature to a ſingle principle? The action of repulſion is an idea equally conceivable as that of attraction, although it be not equally generaliſed as a property of bodies. But let us conſult nature, and we ſhall find, that there is in every body a repulſive principle, as evidently as there is a principle of attraction; therefore, without having the principle of repulſion generaliſed, as has been happily done with regard to that of attraction, our philoſophy is imperfect, and muſt be ſubject to that abſurdity of attributing the ſame or ſimilar effects to different or diſſimilar cauſes. In my theory of heat, I have endeavoured to generaliſe the principle of repulſion; how far ſuch a theory may reſtore to natural philoſophy that conſiſtency which is ſo neceſſary in every part of ſcience, remains to be decided by the learned world.

Let us now proceed to ſee the effects of our inaccurate ſcience and imperfect philoſophy; and, we are to take for example the reaſoning of philoſophers, which has been already ſtated, with regard to the ſubject of heat and cold.

I have ſhown, that natural philoſophers have ſo far departed from the rules of reaſoning in ſcience, as to ſuppoſe that heat could have all the properties of light, and none of its own; ſuch a miſunderſtanding as this could not happen in mathematics, in which men have diſtinct ideas of the objects about which they reaſon. We muſt therefore impute this error to the imperfect ſtate of the ſcience of phyſics, in which philoſophers reaſon concerning things of which they have not formed clear and accurate ideas, in diſtinguiſhing as well as aſſimilating their knowledge.

It muſt not be alledged, that, according to my own theory, light and heat are things commutable; conſequently, that there cannot be any error in attributing to the one what may be conſidered as the property of the other. If light and heat be only terms commutable, and not diſtinct ideas formed in our ſcience, we ought to aboliſh the confuſion of uſing different terms; if the terms again are proper, and belong to actual things, we ought to be the more accurate in diſtinguiſhing when theſe two things, which are commutable, act differently in their reſpective capacities; the commutability of thoſe two things, which are diſtinguiſhed, ſo far from implying or juſtifying any confuſion of our abſtract ideas, light and heat, truly aſcertains their difference. Thoſe two ideas, therefore, can no more be confounded, in the ſcience of phyſics, than a circle and a ſquare might be in that of mathematics, if thoſe two ſciences are equally purſued.

It is not the particular error of thoſe philoſophers who have thus confounded our ſcientific ideas, but it is the general error of our proceeding in phyſical ſcience, in which things are often not diſtinguiſhed with ſufficient accuracy, or in which our ideas are ſuffered to be too vague, in not having been properly analyſed, for excluding every other idea, as is always done in mathematics. It is this inconſiderate manner of proceeding in phyſical ſcience, which, when employed in natural philoſophy, along with mathematical truths, diſcredits that ſcience, and obſtructs the progreſs of philoſophy.

It may indeed be alledged, that it is impoſſible to have always clear perceptions of thoſe ideas in phyſical things, as we have not thoſe conceptions in our mind, but muſt be ſucceſſively informed from without; whereas, in mathematics, where the ideas are all of our own conſcious formation, we have it in our power never to confound one idea with another. This argument, however, though ſtrictly true, cannot juſtify the error or tranſgreſſion; for, we have equally clear conceptions of ſenſible objects, and of phyſical events, as we have of mathematical ideas; and, though we have to acquire our knowledge of thoſe things ſucceſſively, from external information and the judgment of our mind, we ought never to employ any of that acquired knowledge, in our ſcientific reaſoning, until it be analyſed and clearly diſtinguiſhed, which our vulgar notions are not *. The abſtract ideas of light and heat, *e. g.* have no leſs diſtinct properties in our conception when truly analyſed, than thoſe which belong to the abſtract ideas of a circle and a triangle. But, how often are the terms *light* and *heat* employed in ſcientific reaſoning without being properly analyſed? This may be illuſtrated.

If, in violation of thoſe univerſal rules of ſcience, the term *calorique* (for example) ſhould be employed in phyſics, while as an idea it is unknown, and while the properties of that thing are not clearly aſcertained ed in being diſtinguiſhed from every other thing, What would be the effect of generaliſing that ſcience, or employing it in natural philoſophy? It would only lead us into error, and thus vitiate the ſcience or philoſophy in which it were employed. This is not the caſe with the terms of *ſenſible* and *latent heat*, ſo far as thoſe terms belong to real ideas, and ſhall be properly diſtinguiſhed from each other, as well as from every other thing. The employment then of thoſe terms in ſcience muſt tend to enlighten, as that of the other is to darken, underſtanding.

---

* I have ſhown, that, in mathematical truths, there is properly evidence, and that in phyſical truths there is reality; ſo that mathematical and phyſical inveſtigations are equally juſt or true, although not equally real. See an Inveſtigation of the Principles of Knowledge, Part II. Sect. VIII.

Let us now conſider the ſtate of our knowledge with regard to heat and cold, in order to ſee the progreſs we have made, and what is to be ſought for in thoſe ſubjects; for, unleſs we ſee the object which we are to purſue, or the purpoſe for which we are to proceed in thus purſuing knowledge, we are not philoſophers,—we act only by the curioſity of the animal man, and not by the wiſdom of his acquired knowledge.

According to the vulgar notions of things, cold is conſidered as abſolutely ſubſiſting in bodies, in the ſame manner as heat; and it is only in more advanced ſcience, that heat is conſidered as a poſitive thing, of which cold is then the negative. But this is philoſophic theory; and, in this progreſs of the human underſtanding, every ſtep ſhould be perceived, in like manner as in the theory of gravitation. Now, I am afraid there are many men of ſcience, who properly underſtand the theory of gravitation, that only believe the theory of heat and cold in prejudice or ſuperſtition, *i. e.* without having ſeen its evidence; I ſhall therefore give my reaſons for being of that opinion, and leave it to philoſophers to reflect upon the conſequence of this manner of proceeding in phyſical ſcience, and of the pernicious effect of this manner of reaſoning in philoſophy.

In the vulgar view of things, or natural operation of the human underſtanding, heat is a quality that may either be or not be in a body; conſequently, this quality heat, conſidered as a thing, may be ſeparable from a body. But this is no leſs the caſe with cold; which, in that ſtate of human underſtanding, has every claim of being a quality of bodies, no leſs independent than is that of their heat, and as ſeparable from them. Thus, in the common ſenſe of mankind, heat and cold are neceſſarily diſtinguiſhed, and alſo the one is known to exiſt poſitively, in negation of the other. For, cold, which in that caſe is properly known by the feeling, is a poſitive ſenſation as well as heat; nor is the effect of cold, in congealing water, leſs poſitive than is the effect of heat, in melting ice. This, however, is all that common ſenſe can lead us to conclude; and, this is all that men of ſcience know, when they ſay *that cold is nothing but the negation of heat.* But a natural philoſopher cannot be ſatisfied in proceeding no farther with regard to heat and cold; he ſhould know the principle on which depends the hardneſs or concretion of bodies which are the effects of cold, and he ſhould know the principle of their ſoftneſs or fluidity which are the effects of heat. For, without knowing the principle upon which the effects of cold proceed, How can he ſay that cold may not be a ſubſtance ſeparable from bodies as well as heat? and, without ſeeing the principle upon which the effects of heat are truly explained, How can he ſay that heat is a thing any more poſitive than cold? It muſt not be here replied, that cold is only the abſence of heat, and therefore muſt be negative, while heat is a poſitive thing: For, if there be nothing poſitive in cold as the proper cauſe of a known effect, and if in bodies there is nothing actually beſides more or leſs of heat, How is it that more and leſs of the ſame thing produce effects that are oppoſite, or contrary in their nature? ſuch are hardneſs and ſoftneſs;—ſuch are the repulſion of the parts of an elaſtic fluid, and the concretion of a ſolid body.

No ſubjects are more intereſting to philoſophy than are thoſe of heat and cold, which at preſent ſeem to be neglected. Nothing has done ſo much honour to ſcience as the inveſtigation of that law of nature by which bodies at a diſtance are mutually affected. But, Are thoſe affections of the conſtituent parts of bodies leſs intereſting, to the human underſtanding, when they approach and make their diſtance appear to us to be an evaneſcent quantity? Are the laws of revolution of Jupiter's ſatellites more important, either to the animal or intellectual oeconomy of man, than thoſe by which the operations of water are conducted, when on the one hand it becomes a hard body, and when on the other it is changed to an aerial ſubſtance?

The vulgar know the weight of bodies upon the ſurface of this earth as well as the philoſopher who calculates the effect of Jupiter and Saturn upon the path of a comet, but, Is a philoſopher to know no more about the evaporation and congelation of water, than that the one is the effect of heat and the other the effect of cold? The natural philoſopher ſhould tell why, or according to what general principle of action, water is evaporated on the one hand and congealed on the other; until this be done, we have not the philoſophy of heat and cold, however extenſive may be our ſcience on thoſe ſubjects. Let us ſtate the caſe, in order to ſee the part which a philoſopher ſhould take on this occaſion.

The general gravitating power of bodies was only learned, in finding the law of nature by which that power acted; whereas, with regard to thoſe of heat and cold, philoſophers ſeem to be contented in knowing the particular effects of theſe powers, without ever inquiring concerning that general law of action which may be inveſtigated in thoſe phyſical effects. But, without the knowledge of that general principle, which muſt always act in bodies, and which muſt always act according to a certain law in giving them either hardneſs or fluidity, ductility or elaſticity, Will ever natural philoſophy explain the phenomena of this earth, as has been done by gravitation with regard to thoſe of the heavenly bodies? Therefore, in order to underſtand heat and cold as general principles, we muſt ſee the different principles by which theſe oppoſite effects are cauſed.

A natural philoſopher, in properly underſtanding the phyſical principles of things, ſurely cannot allow that what he calls cold can be ſeparated from a body, any more than its powers of gravitating and concreting: But, this is only to be underſtood in knowing the conſtitution of bodies, in which cold is an element as poſitive as heat; for, cold in bodies is the negative of heat, as much as heat is the negative of cold. Nor can a philoſopher ſuppoſe that heat is ever ſeparated from a body as heat; he might juſt as well ſuppoſe that an elaſtic fluid were ſeparated from a body of air, when this is compreſſed into a ſmaller volume.

I have endeavoured to explain many of thoſe appearances in the diſſertations before mentioned; it has there been ſhewn, that the matter of heat differs eſſentially from the gravitating matter of a body, as acting upon another principle; and that, according to this conſtitution of things, heat muſt be ſeparable from a body, or variouſly diſperſed and apportioned in bodies, while gravitating matter is, on the contrary, inſeparable in its nature, or cannot be tranſlated in the manner of light and heat.

No doubt this is conſidering matter in a very different view from that in which it is commonly ſuppoſed; but now, the queſtion is not with regard to what philoſophers *ſuppoſe* to be the nature of things; our object is to ſee in what manner philoſophers may attain to the *knowledge* of nature.

In viewing the great ſyſtem of nature, we conceive many bodies as inſulated in the heavens, and conſtantly receiving in light the influence of the ſun; now, when that light, inſtead of being reflected by a refulgent body or tranſmitted by one that is tranſparent, ſhall be extinguiſhed by a black body, which is thus heated, Can we ſuppoſe that it were either in quality of heat that the influence of the ſun had been tranſlated from the luminary to the body that is to be illuminated, or that it were in quality of light that the ſolar ſubſtance now actually ſubſiſts in the heated body? But, Are the bodies upon the ſurface of this earth, although not inſulated in the manner of the heavenly bodies, to be conſidered in any other manner, with regard to light and heat, than are thoſe heavenly bodies which are illuminated and heated by the influence of the ſun?

According to the theory which I have given, heat is conſidered as the effect of the ſolar ſubſtance acting in a body; but, cold has there been repreſented as a quality of bodies depending on their gravitating matter immediately, and only more remotely upon the abſtraction of that which is the cauſe of heat, conſequently that cold is a thing that can no more be ſeparated from or tranſlated among bodies than may be their weight. But now we have an experiment in which there would ſeem to be cold radiated from a body, and reflected by a ſpeculum in the manner of light; were this concluſion to be admitted as a truth, it would certainly be a confutation of my theory of heat and cold.—The confutation of an erroneous theory is always a ſtep in ſcience, and naturally leads to the diſcovery of truth. This, therefore, is a ſubject to which I would wiſh to turn the attention of philoſophers.

At preſent I have only to obſerve that

the alledged experiment does not properly confute my theory, if it ſhall be admitted that this theory is nothing but the generaliſation of phyſical truths hitherto uncontraverted.

The experiment of irradiated and reflected cold, indeed, refutes thoſe principles, with regard to which at preſent perhaps all natural philoſophers are agreed, and upon which a great part of our natural philoſophy now ſurely depends. This therefore makes it ſo important to have that experiment well examined, and properly explained. But it is no leſs important, to have M. de Sauſſure's experiment, of reflected heat, properly examined. I have endeavoured to ſhew that the reaſoning of thoſe philoſophers with regard to that experiment is erroneous. But I may be conſidered as not being an impartial judge on this occaſion; and that I may be prejudiced by my particular theory of heat and cold, which that experiment, according to the explanation of thoſe philoſophers, would certainly refute. I would therefore recommend it to thoſe men of ſcience who have the opportunity, that they would make proper experiments, in order to reſolve thoſe queſtions ſo important to natural philoſophy.

Theſe men of ſcience, theſe eminent natural philoſophers, have ideas with regard to heat which are altogether inconſiſtent with my theory; we cannot both be right; and, it is a reproach to ſcience to have different opinions upon the ſame ſubject. It is therefore the intereſt of natural philoſophy to have theſe ſcientific opinions carefully examined, by being analyſed to their principles, in order to ſee that evidence on which every theory muſt proceed, and by which it muſt be then believed.

It is ſurely ſome neglect of this kind which could induce philoſophers to ſuppoſe that heat may be a thing moving like light, and may be reflected by a mirror, and concentrated in a focus. If philoſophers ſhall allow themſelves to entertain ſuch ideas in their ſcience without knowing why, or without having traced thoſe ideas to an evidence which cannot be diſtruſted, they may as well allow themſelves to ſuppoſe that cold may be irradiated like light, and be reflected and concentrated as well as heat. But this would be the fiction of a mind dreaming in ſcience, and not that accurate operation of the human underſtanding which proceeds on knowledge, and thus perceives things as they are truly in the deſign of nature. No body ſuppoſes weight to be ſeparable from a ſtone, or from the moon in which that general principle of action was inveſtigated; but, Is the expanſion of bodies a principle equally underſtood as is that of their weight? and, Can a philoſopher, who has proceeded no farther, ſay, why the principle of fluidity and expanſion either may or may not be ſeparable from a body?

As heat and fluidity, cold and concretion, light and gravitation, are the chief principles of phyſical bodies, or the prime agents in the material ſyſtem, I have treated of thoſe principles at ſome length, in the diſſertations now mentioned.—Whether I have reaſoned right or not, I have there endeavoured to take general views of a ſubject moſt intereſting to philoſophy; and I have there endeavoured to trace theſe ideas to their natural evidence. I now wiſh philoſophers would attend to the neceſſary diſtinction of thoſe things; and not confound heat with light, light with cold, and cold with ſomething ſeemingly inconceiveable; for, by reaſoning in that inconſiderate manner, without clearly diſtinguiſhing things which are in their nature different, ſcience will never be promoted; and, without generaliſing phyſical truths, ſo as to form theory in a ſcientific arrangement, What ſignifies the multiplication of experiments which have no proper order or deſign?

Accident no doubt often is the means of making valuable diſcoveries, ſuch as is this very experiment of cold which we have been now conſidering; but, it is only to the philoſopher that accident can ſuggeſt a ſcientific truth; to the animal, to the ſavage, or even to the vulgar in a learned nation, natural events draw to no concluſion beyond the ſatisfaction of their animal deſires; and, the moment that an animal perceives in natural events a *general*, that moment natural philoſophy is in his mind begun; therefore, it is only by generaliſation that philoſophy proceeds.—This however is a propoſition which is only properly to be underſtood in the ſcience of metaphyſics; and of this I have treated largely, in an inveſtigation of the principles of knowledge, to which I now beg leave to refer.

Having thus conſidered the general object in our theories of heat and cold, let us now take a more particular view of thoſe qualities of bodies, by which ſcience is to proceed in generaliſing events for the purpoſe of philoſophy.

Bodies are conſidered as made up of many qualities; but, ſcience muſt generaliſe that ſubject, in making us underſtand the different kinds of qualities. Thus there are, firſt, ſenſible qualities, in which there is an external cauſe acting and informing our ſentient mind, which is then paſſive in being made to know, feel, or ſuffer. Secondly, there are perceptible qualities, which do not reſpect the paſſion of our mind, but repreſent a ſtate in which we conceive external bodies to ſubſiſt; this then is magnitude and figure. Laſtly, there are active qualities, which we judge from knowing the different ſtates of bodies; and theſe we conſider as powers in bodies by which their ſtates, whether of motion or reſt, may be changed. Now, in generaliſing thoſe acting powers, we muſt ſtudy the order of the events, and attend to the circumſtances or conditions of the action. We thus form a general principle for explaining natural appearances, by aſſimilating thoſe actions which are properly diſtinguiſhed.

In thus conſidering natural bodies as compoſed of principles which have power and energy, we may now obſerve, that there are fixed and incommutable powers or principles in bodies, as well as thoſe which are more or leſs changing and commutable. According to my phyſical notions, the fixed and incommutable principles of bodies are, firſt, that of gravitation or coheſion; and, ſecondly, that of concretion, which is diſtinctly different from gravitation or coheſion. The moveable and commutable principles, again, are the two different ſpecies of heat, *i. e.* the heat of fluidity and that of expanſion, principles of action which are naturally oppoſed to the fixed principles, the one to concretion, and the other to gravitation. But thoſe commutable principles of bodies are alſo mutable in relation to the general ſyſtem of bodies, in the regulated motions of which we perceive deſign and wiſdom. It is in this manner that light is conſidered as the tranſlation of matter from one body to another, when theſe are perfectly inſulated; and, in electricity we perceive a moving cauſe for matter of the ſame kind as that which moves in light; but the laws of this laſt ſpecies of action are not perhaps ſo well known as thoſe of the other, and are extremely different.

But here we have another object for our conſideration; this is the emanation of light, from certain bodies, in the act of burning. Now the object of ſcience is to inveſtigate the principle upon which this appearance actually proceeds; and, this is a ſubject intimately connected with that which, in the theory of light and heat, we have been endeavouring to inveſtigate.

No ſubject more intereſting to the natural philoſophy than is that of fire; and, no ſubject in which philoſophers have more miſtaken their principles, than in the explanation which they have attempted to give of this important operation. It is from fire that light is made to proceed, though variouſly in relation to its ſeveral ſpecies; and, it is particularly from burning coals that the ſpecies of light moſt powerful in exciting heat is made to appear. This particular ſpecies of fire, therefore, is now to be the ſubject of examination; and, in this, my chief object will be to ſhow, how dangerous it is in ſcience to proceed upon an erroneous analyſis, and how unphiloſophical to generaliſe a matter of fact, or phyſical principle, without being accurately diſtinguiſhed.

While the ſcience of chymiſtry has been making great progreſs in the analyſis of bodies, and thus procuring principles for natural philoſophy, there has been made one inadvertent ſtep, which, in my opinion, muſt prevent the benefit which natural philoſophy might otherwiſe derive from thoſe eminent diſcoveries.

Amids the brilliant ſucceſs of thoſe chymical experiments, philoſophers have been led to generaliſe the principal heat in the burning of bodies, without analyſing properly that operation, and in miſapplying the actual knowledge which we have of heat. I am now to give a ſhort view of this miſunderſtanding in a ſubject ſo naturally connected with that of thoſe experiments which we have been analyſing; and I ſhall endeavour to explain the various phenomena of fire, conſiſtently with our theory of light and heat.

PART V.

Light inveſtigated as the Principle of Fire in Burning Bodies.

SECTION I.

Combuſtible Bodies examined with regard to the Nature of Burning.

IN my chymical diſſertation upon the ſubject of phlogiſton, I have examined the new theory of burning, or the principle of fire in burning bodies, according to the doctrine of calorique. The philoſophers, who made the great diſcovery of oxigenating many ſubſtances by means of vital air, thought thus to explain all appearances in thoſe burning and oxigenating bodies, without any other principle of fire beſides that which correſponds to what Dr Black had termed *latent heat*, or what properly, in this caſe, is the heat required in order to preſerve the fluid elaſticity of the vital air. This is what the French philoſophers have named *calorique*, ſo far as there is any reaſonable meaning in that term.

In order to ſhow that this was an erroneous explanation of burning, and that there is truly in the conſtitution of certain bodies a ſubſtance that may be properly conſidered as phlogiſton, I firſt examined thoſe phlogiſtic bodies in their decompoſing ſtate, when the principle of fire appears. Here it has been made evident, from facts which I believe will not be controverted, that thoſe appearances of fire cannot be explained by any theory of heat, ſo far as yet known.

But this phlogiſtic ſubſtance, when decompoſing in burning, may be conſidered as diſperſed in light and heat, and thus loſt to the bodies of this earth; therefore, it appeared neceſſary to look out for the means by which the continual waſte, of that ſubſtance ſo uſeful in the oeconomy of the world, might be repaired. It was vegetation, then, that I conſidered as the proceſs in which nature has placed the compoſition of phlogiſton; and, it is by the influence of light that I conſidered the combination formed, of that ſolar ſubſtance with the other chymical elements of bodies. I have there given many arguments, for believing that this combining proceſs actually takes place on that occaſion; and that it is part of the phyſical ſyſtem, by which this earth is preſerved as a living world.

Thus I formed a probable theory, for the purpoſe of directing future experiments, as well as to be compared with thoſe facts or phyſical principles which are already known. I alſo endeavoured to confirm that theory of phlogiſton, in ſubſequent diſſertations upon the powers of matter and appearances of bodies; where I attempted to explain, upon the principle of phlogiſton or the ſolar ſubſtance, ſome of the eminent qualities of bodies.

In theſe diſſertations, when treating of luminous and burning bodies, I ventured to give a theory, which I am now more fully to lay open. I then aſſumed a principle, in the theory of fire; at preſent, I am to prove that principle, and to illuſtrate the theory, in applying it for the explanation of phenomena in burning bodies. This is the ſtate of the ſubject, previous to the preſent diſſertation.

Here I have been employing a new principle, for explaining certain anomalous appearances with regard to heat; and this principle, which is that of inviſible light, has been inveſtigated from the examination of that light which is made to appear in the burning of bodies. I am therefore again to examine thoſe phlogiſtic bodies burning and emitting light, in order to inveſtigate, if poſſible, the true principle of fire, which has been hitherto ſo much miſunderſtood among philoſophers.

We have now found, that there is an inviſible ſpecies of light continually moving from bodies, as well as that ſpecies by which we are made to ſee. There are alſo two ſpecies of heat; for, beſides the moveable or diffuſible heat in bodies, by which we are made to feel, there is another ſpecies, by which the powers of hardneſs or concretion in bodies is overcome. Now, all thoſe different modifications, of the ſame ſolar ſubſtance, are commutable or mutually convertible. But, there are other modifications of this ſolar ſubſtance in bodies; and there are, in the conſtitution of thoſe material things, other purpoſes which that ſolar ſubſtance has to ſerve. Here, no doubt, is a ſubject moſt intereſting to natural philoſophy,—a ſubject which, I think, the preſent ſtate of our ſcience may enable us to illuſtrate.

Beſides the commutable modifications of the ſolar ſubſtance, termed light and heat, we have now to treat of another, which may be conſidered as the modification of fixed light in bodies, or that ſubſtance which appears in fire, and upon which depends the burning of bodies.

Former chymiſts were ſenſible of the neceſſity for a principle of this kind, which they termed phlogiſton, in order to explain the appearances of burning bodies. Our preſent chymical philoſophers, who have made great progreſs in the ſcience, diſcovered much falſity in the theories of thoſe former chymiſts, and corrected thoſe errors, have endeavoured to explain all the appearances of burning by a theory of heat which Dr Black had diſcovered, and which he named latent heat. At leaſt, if that theory of heat, which theſe chymiſts have termed *calorique*, be not *latent heat*, it is not any other thing in nature, ſo far as I know; and this new principle is not deſcribed ſo as to be any otherwiſe underſtood.

I ſhall now endeavour to ſhow the inconſequential reaſoning of that theory, in which *calorique* is ſuppoſed to explain the phenomena of burning, and in which fire is ſuppoſed to proceed without the aid of any phlogiſtic matter.

In that chymical diſſertation which I had the honour to read in this Society, I took, for an example in the burning of bodies, a very accurate experiment, which had been firſt made by Mr Cavendiſh, but which was carried to great perfection in France,—an experiment which actually gave occaſion to the formation of that theory of *calorique* which it was then my object to refute. At preſent, I am to take a different example in the ſame ſubject, the burning of bodies; and, from this new example, I ſhall confirm my former reaſoning, in obtaining a ſimilar concluſion, founded upon a matter of fact which was not then ſo fully employed. In thus refuting the doctrine of calorique upon a new ground, we ſhall have an illuſtration of that principle, in the commutation of light and heat, which has been ſo much the object of the preſent diſſertation; and we ſhall thus obtain a new fact, or acquire a new principle for the explanation of fire.

Upon that former occaſion, it was the inflammation of bodies which afforded ſo notable an example for the purpoſe of our ſcience; at preſent, I am firſt to take the combuſtion of bodies as an example, in order to explain the appearances of fire; and, therefore, a coal muſt be the ſubject of our experiment and reaſoning.

In that chymical proceſs, in which the combuſtible ſubſtance of coal is decompoſed by the oxigenating principle of vital air, there are produced two diſtinct effects; firſt, by the oxigenating of the gravitating carbonic ſubſtance, there is produced fixed air, or carbonic acid in an elaſtic ſtate. Secondly, in thus changing the nature of the coal, there is produced a great quantity of light and heat; it is only this laſt event, or effect, with regard to which there is any difficulty, or any diſpute to be made; and, with regard to this, there are juſt two different opinions. On the one hand, the phlogiſtic theory maintains, that in this chymical proceſs, of oxigenating the fixed carbonic ſubſtance by the vital air, the phlogiſtic matter of the combuſtible body is liberated from its former combination; and, that it is this extricated ſubſtance which, in thus eſcaping from the body, exhibits the phenomena of light and heat.

On the other hand, the antiphlogiſtic theory ſuppoſes, That this heat is acquired by a certain degree of condenſation of the vital air in oxigenating the carbonic ſubſtance; or, in other words, That the latent heat of this elaſtic fluid, which is ſuppoſed to be ſo condenſed, is then transferred to the burning coal, which is thus heated; and that the light, which appears in burning,

ing, is then emitted in conſequence of the heat acquired from the *calorique* of the decompoſed or condenſed air.

This being the antiphlogiſtic theory, then, if it can be ſhown, that the decompoſing proceſs does not heat the coal, but that, on the contrary, the coal, notwithſtanding the moſt favourable circumſtances for its burning or being decompoſed by oxigenation, actually ceaſes to burn for want of heat, it will be proved, that the heat, which appears in fire, is not the immediate effect of the burning; and that, *a fortiori*, it is not the *calorique*, or elaſtic heat of the vital air, which heats the coal, and appears in fire. This then is the propoſition which is now to be proved.

Let a conſolidated piece of charcoal [*],

---

[*] There is, in many parts of Britain, a mineral coal naturally charred and extremely conſolidated. It is this ſpecies of coal that I recommend for making a moſt accurate

(ſuch as is to be got in great perfection from the mineral kingdom) be heated to the greateſt extremity of incandeſcence; and then let it be expoſed, inſulated, to the atmoſpheric air. Here is a coal in the moſt perfect ſtate of burning, or with the moſt favourable conditions for oxigenating with the atmoſpheric air. Were this body then to conſume by itſelf, as it does when aſſociated with other burning coals, there might be ſome pretext for alledging that the proper heat of burning was preſerved by the extrication of *calorique*, or the latent heat of the vital air. But if, notwithſtanding the proper conditions for the burning of the coal, and the extrication of that *calorique*, the heat of the coal ſhall decreaſe and the

curate experiment; and, it is this coal which appears to me to cool as quickly, in atmoſpheric air, when in a ſtate of incandeſcence, as if expoſed only to the azotic part of that fluid. Now this could not poſſibly happen, if heat were generated by burning. But, even with a much more imperfect body of this kind, a ſufficiently ſatisfactory experiment may be made, which gives us the opportunity of proving the propoſition *a fortiori.*

the burning ceaſe, we muſt neceſſarily conclude, that it is not the *calorique*, or latent heat of vital air alone, by which the burning coal receives its heat, but that there is another cauſe for this appearance, which cauſe it is the proper object of ſcience to inveſtigate. But the coal, in the ſituation here deſcribed, certainly extinguiſhes; conſequently, the propoſition is proved, if we have reaſoned right.

To ſee the force or concluſive nature of this argument, it muſt be obſerved; firſt, that I have not ſuppoſed no heat to be acquired by the condenſation of the vital air, ſo far as that takes place in this operation, which is extremely doubtful; I only ſuppoſe, that there is not ſufficient heat to be derived from that ſource *. Secondly, I have not ſuppoſed that an incandeſcent coal, although not continuing to burn with atmoſpheric air, might not burn and be conſumed with pure vital air; for, as vital air is a neceſſary condition for the burning of this coal, as well as is a certain degree of heat, that body may perhaps burn in a leſs favourable ſtate of the one condition, when that of the other is more favourable. This however is a ſpeculative point with which we are not immediately concerned.

---

* It muſt be allowed, that, ſo far as vital air ſhall be condenſed in oxigenating the ſubſtance of a burning body, ſenſible heat may be procured upon that occaſion. In the preſent caſe, however, all that can poſſibly be acquired in this way is a ſmall thing, compared with the quantity

The only queſtion at preſent to be decided is this, Does the heat of the coal, burning in atmoſpheric air, ariſe from the operation of the vital air upon the ſurface of the body, or does it require another cauſe? Now, if the burning be the immediate

quantity of heat which is conſtantly abſtracted by the atmoſphere in contact with the burning body, and does not deſerve to be mentioned here, unleſs it were to acknowledge the doctrine of heat and condenſation, although this is not a caſe in which it ſhould appear; for, here the oxigenated ſubſtance has become an elaſtic fluid.

diate cauſe of heat, as the application of atmoſpheric air is the proper cauſe of burning, How ſhould the application of air cool the body in which it is the cauſe of heat?

If a ſingle coal, burning to the beſt advantage, cannot generate heat upon the whole, *i. e.* cannot gain more heat from the air than what it neceſſarily loſes in that oxigenating operation, How is the union of thoſe bodies to increaſe their heat? This muſt be either by increaſing their gain, or by diminiſhing their loſs. But, it cannot increaſe their gain; for, by the preſent ſuppoſition, heat is only acquired by the free communication with the atmoſphere, which the uniting of the coals prevents; therefore, it can only be by diminiſhing their loſs of heat, which is neceſſarily carried away by the circulation of the air. But now, How are we to form this compound eſtimate?—on the one hand, by uniting the burning coals, we diminiſh their loſs of heat; but we alſo, in the ſame proportion, it is to be preſumed, diminiſh their gain, or the generation of their heat. On the other hand, by ſeparating the coals, we increaſe the cauſe by which their heat is loſt; but, at the ſame time, we increaſe the cauſe by which their heat is generated. That it is not by diminiſhing the circulation of the atmoſphere that their heat is preſerved, will appear from this, the heat of the fire is increaſed, the more we force cold air to flow among theſe coals; and this alone ſhould decide the queſtion. But, this being the cardinal point to be proved, we muſt conſider it in every view, ſo as to leave no room for miſunderſtanding or diſtruſt.

It may perhaps be ſuppoſed, that the azotic part of the atmoſpheric air ſhall cool the burning body more than the vital part heats it. But this ſuppoſition, however it may be deemed poſſible, is inapplicable in the preſent caſe, and could ſerve no purpoſe, unleſs it were to ſupport the theory of *calorique*.

To ſee this, we have but to examine the matter of fact in the following manner. Were the compound atmoſpheric air in any reſpect inſufficient to maintain the burning heat in this inſulated coal, according to the ſuppoſition, How is it that the ſame fluid is found ſufficient to ſupply the means ſo amply for the burning of our fires? that is to ſay, if the atmoſpheric air, by oxigenating a fire of coals, ſupplies abundant heat to the ſurfaces of thóſe burning bodies alongſt which it is made to flow, Why ſhould it not in like manner ſupply heat to the ſurface of the inſulated burning coal, expoſed in the beſt poſſible manner to that heating operation?

It muſt not be ſaid, that the coal in the fire is leſs cooled by the atmoſphere, than is the ſingle coal; for, we are to conſider, that the azotic and carbonic air is no leſs heated by the fire than by the inſulated coal, if burning with an equal intenſity; there is equally, in both caſes, a conſtant application of cold air to be heated, in contact with the ſurface of the fire, and a conſtant abſtraction of that air thus heated; therefore, the heating and the cooling cauſes being in both caſes equal, the fire ſhould equally continue to burn in both.

In every view of the ſubject, therefore, there is reaſon to conclude, that coals, in the burning ſtate, whether inſulated or aſſociated, are not preſerved in their ſtate of incandeſcence, or burning heat, by the extrication of the latent heat of vital air, or that which is the principle of its elaſtic fluidity. But, this compariſon, of the inſulated and aſſociated caſes of burning, being an intricate ſubject, in which many things are to be conſidered, the ſmalleſt inattention or overſight in reaſoning may greatly miſlead the judgment on the whole; therefore, this caſe may be illuſtrated, by examining the ſubject more particularly.

When burning coals are ſo placed in relation to each other, as to leave ſufficient ſpace for the free aſcent of the heated atmoſphere, and for the ſupply of the oxigenating principle by the circulation of the air, the fire continues to burn, and the coals to be conſumed. But, when theſe coals thus burn together, it is not by loſing leſs of their burning heat, by the circulation of the air among them, than if they were expoſed inſulated to the atmoſphere, in which laſt caſe they ſoon extinguiſh. This then is the fact or phyſical truth that we now want to aſcertain.

In order to ſee this, let us ſuppoſe the coal, which, when ſolitary, would be extinguiſhed, ſuſpended in the atmoſphere, and to be ſurrounded with other burning coals likewiſe ſuſpended, ſo as to form a circle round the ſingle coal, and at a proper diſtance, for the free aſcent or circulation of the atmoſphere. In this caſe, the central coal will continue to burn, as long as the ſurrounding coals are incandeſcent, or emit ſufficient light. Now, the queſtion is, What this coal receives from the burning bodies around. It is to be preſumed, that it can only receive either light or heat; but, we are not now examining light; it is only heat with which we are at preſent concerned.

That it is not heat which the central coal is now receiving, will appear by conſidering, that the ſurfaces of all thoſe coals are equally burning, and equally giving heat to the cold atmoſphere, which is conſtantly flowing upwards along them. Therefore, I ſay, that thoſe ſurfaces loſe no leſs of their heat, by this circulation of the air between them, than if they were burning at the greateſt diſtance from each other; for, it is only by the circulation or aſcent of the atmoſpheric air along their ſurfaces that they burn, or, according to the theory of calorique, that they are heated; and, it is by that circulation of air only that they are cooled. Therefore, if they are cooled by a free circulation of air, they are neceſſarily heated in proportion ; and the coal, which is burning inſulated in the atmoſphere, cannot be leſs heated or more cooled, than burning coals among which a ſtrong ſtream of cold atmoſpheric air is made to paſs, which is the operation of the bellows ; yet, in the one caſe, the ſingle coal is cooled, and, in the other, the fire is made to burn more fiercely.

It muſt not be alledged that the heat, which is abſtracted from the one burning coal, is made to heat the ſurface of the burning coal which is oppoſite ; the abſtracted heat of each coal, in the ſituation of things which we have propoſed, or the atmoſpheric fluid which is heated by the contact of the burning ſurface, flows upwards, in communicating its heat to the ſuperior part of the coal ; it cannot heat the oppoſite coal ; for, that would be to move in two different directions at the ſame time. Nor are we to admit of ſuch a thing as radiating heat; that is a ſubject which we have already diſcuſſed in a former part of this diſſertation.

Therefore, it muſt not be ſaid that the burning coal is receiving any heat from the ſurrounding coals, or that it is loſing leſs of its own heat, by the circulating atmoſphere, than if it were burning at the ſame rate ſingle; for, this would be to maintain, that coals generated more heat in burning together, than in burning ſingle. But, the theory of fire, which we are now refuting, maintains, on the contrary, that the burning body acquires heat *only* in proportion to the atmoſpheric air which it conſumes; and, I have now ſhown, that burning coals, whether ſingle or united, equally loſe heat by the circulation of that atmoſphere which makes them burn.

It follows, that a ſingle coal burning inſulated in the atmoſphere is loſing no more of its heat, by communicating with the ſurrounding fluid, than when it burns ſurrounded by other burning coals. In the one caſe, indeed, the coal continues to burn ; and, in the other, it is certainly extinguiſhed. But this is not becauſe more heat is abſtracted from it in the one caſe than in the other, but becauſe it acquires more heat when burning in the aſſociated ſtate. This is directly contrary to the antiphlogiſtic theory of fire ; and, it ariſes from a cauſe which cannot be confounded with *calorique*, and which ſhall be diſtinguiſhed as different from any ſpecies of heat.

I am ſorry to be ſo prolix ; but I find it neceſſary, in order to overcome prejudices, to endeavour to conſider the ſubject in every point of view, and under every different expreſſion. Even men of ſcience will often conſider things with vulgar notions, which muſt miſlead philoſophy ; it requires the moſt accurate analyſis of natural operations in order to diſcover cauſes ; and, here is a natural operation which, for want of that analyſis, has been greatly miſunderſtood.

We are not now inquiring how a fire of coals maintains its burning heat; that queſtion, ſo important in philoſophy, ſhall be reſolved, after we have diſcuſſed this cardinal point, viz. If a coal, in the moſt perfect ſtate of burning, ſhould be cooled by the application of atmoſpheric air. Now, according to the antiphlogiſtic theory, or that of *calorique*, this is impoſſible; for, the coal is ſuppoſed to be in the greateſt ſtate of incandeſcence; conſequently, being freely expoſed to the atmoſpheric air, it muſt generate the greateſt quantity of *calorique*, or acquire *calorique* at the greateſt rate, and thus be heated in every point of its ſurface which is all burning. But, to ſuppoſe it alſo to be cooling in any degree, while it is heated in the greateſt, is a contradictory propoſition, or a fact plainly inconſiſtent with that theory. Now, the matter of fact, or ſubject of experience, is this, that a coal, in the ſuppoſed ſituation, is actually cooled by the atmoſpheric air, which makes it burn; on the contrary, a fire of coals, which burns by the ſame atmoſpheric air, inſtead of loſing its burning heat, is made to increaſe the intenſity of its burning, the more that the cold atmoſphere is made to paſs through among its coals.

If it were not for the difficulty of removing rooted prejudices and received notions, this argument, which has now been drawn to ſuch a length, might have been compriſed in a few words. For, if a body, in burning, is heated by the atmoſphere, and if it is burning all over its ſurface, How is it conceivable, that it ſhould be at the ſame time cooled by that atmoſphere which is heating it? In this caſe, to ſay, that, though the air or *calorique* heats the burning body, it does not heat it ſufficiently to preſerve its burning, is plainly to acknowledge, that it is not the *calorique* that gives heat to fire; for, if the *calorique* be not ſufficient to entertain the fire of a body once heated to the greateſt degree, What is the cauſe of that immenſe quantity of heat which is generated, when, from the ſmalleſt ſpark, the greateſt conflagration is produced?

I ſhall now ſtate the propoſition, which has been ſo fully illuſtrated, and which is to be a principle in our further reaſoning.

If a fire of coals is heated by means of atmoſpheric air, which makes it burn, then, a ſingle coal, in a proper ſtate of incandeſcence, ſhould not be cooled by that atmoſphere, but ſhould continue to burn and be conſumed; therefore, the extinguiſhing of this coal proves the propoſition, or aſcertains this truth, That the atmoſpheric air, which is the means of burning, is not the immediate or proper cauſe of that heat which appears in fire; and, that it requires another cauſe, in order to maintain the neceſſary burning heat in a fire of coals.

Now, in order to underſtand this intricate operation which takes place in a fire, and in which there is produced ſo much light and heat, let us analyſe the ſubject, by diſtinguiſhing the light which is the immediate effect of heat without burning, and that light which does not proceed immediately from heat, but which is proper to the burning. We ſhall thus diſtinguiſh heat as the cauſe of burning, and heat as the conſequence or occaſional effect of burning, but not as the abſolute or immediate effect. For, as I have now ſhown, that the burning of a coal does not produce or entertain the heat by which it was made to burn, this heat, which is certainly entertained in a fire of coals, muſt require ſome other cauſe; and, this is now to be the ſubject of inveſtigation.

A coal, expoſed to the atmoſphere without the incandeſcent heat, is not oxigenated by the vital air, nor conſumed, as it is in burning; neither is this coal changed or conſumed by the greateſt heat of incandeſcence, unleſs expoſed to the atmoſpheric air, or the oxigenating principle which it contains. But, in the burning of a fire of coals, there is neceſſarily a conſtant abſtraction of a great quantity of heat, in the circulation of the atmoſphere by which it burns. The incandeſcent heat, therefore, which is neceſſary to the burning of that fire, would ſoon be carried away from the maſs of coals, however great, as it is from the inſulated coal; and then the fire would be extinguiſhed in the burning maſs, in like manner as it is in the ſingle coal. Now we are inquiring, How it is that this burning heat is preſerved in the one caſe, and not in the other.

In order to ſee this, we are to conſider, that, in the caſe of a ſingle coal, all the light which is emitted from that body is entirely loſt to that burning coal; it traverſes the tranſparent medium with which the coal is ſurrounded, until it meet with ſome body or ſome cauſe by which it may be arreſted, extinguiſhed, or converted into heat. This burning body, then, is conſtantly expending a great quantity of extremely *heating light*, without being in any degree heated by this light which is emitted. But, in the caſe of coals burning in the aſſociated ſtate, which is termed a *fire*, it is very different; here, each coal is receiving the light of all the coals which are burning around it, while theſe are black bodies moſt fit to extinguiſh that light; and, we have already found, that this light is of that ſpecies which is extremely powerful in exciting heat. Now, all the light, which is generated within this fire, muſt be thus arreſted by the opake bodies, and converted into heat. Therefore, in a fire of coals, there is an immenſe ſource of heat, a ſource which is not in a coal when burning ſingle.

Upon this principle, we muſt ſee a growing power in fire; a power, not only capable of maintaining its own devouring nature, but of increaſing, from the ſmalleſt ſpark, to the greateſt conflagration.

To illuſtrate this, let the ſmalleſt particle of burning coal be ſo placed among ſimilar particles, not actually burning, but in a condition to burn with the addition of heat; in that caſe, thoſe ſurrounding particles receiving that addition of heat from the focus, are made to burn; and, in burning, theſe coals return that heating ſpecies of light to the focus, for the increaſe of its burning. But, this is no other than a deſcription of what actually happens in reality, and upon every ſcale, from the catching of the ſpark in tinder, to the kindling of the city or the foreſt. Fire, like animal or vegetable life, is propagated in a growing ſeries. Invert this proceſs, again, and ſeparate the burning coals, ſo that they do not receive each other's light, the heat gradually diminiſhes, and the fire is ſoon extinguiſhed.

We thus have every appearance of fire explained; for, in this diſpoſition of things, where the light, emitted from the burning coal, is employed in heating coals ſupplied with every other neceſſary condition for burning, the fire proceeds without any relaxation or decay, until ſome of the conditions are changed, or until all the coals are conſumed.

It muſt not be alledged, that this light, which is the cauſe of heat in fire, is emitted from the burning body in conſequence of that heat which is procured from the atmoſpheric air; for, if the burning coal emits its light in conſequence of its acquired heat, How comes it that this coal is cooled, though burning freely in the atmoſphere? Conſequently, it is not heat which is the cauſe of light in fire; but, on the contrary, it is the light of fire which is then the cauſe of heat.

In thus explaining fire, we have the confirmation of this doctrine, That there is an internal principle of fire or phlogiſton latent in combuſtible bodies; and that this principle, when extricated from its chymical combination, acts its part in the operation of burning. Now, this luminating principle is no other than a certain modification of the ſolar ſubſtance, which is in the conſtitution of combuſtible bodies, a modification diſtinctly different from that of heat, by which the ſame ſpecies of light is made to be emitted from many bodies. If we ſhall thus be found to have diſtinct principles, by which the natural conſtitution of bodies, whether heavy, hard, fluid, luminous, burning, hot, or cold, may be reaſonably conceived, here is a ſubject which ſhould excite the inquiry of natural philoſophers. But, theſe principles neceſſarily exclude the ſuppoſition of heat moving from a body as heat, however that principle of expanſion and fluidity may be tranſlated among bodies by means of its commutation and diffuſion; they alſo exclude the idea of having the principle of cold ſeparated at all from a gravitating body, in which that power is neceſſarily as inherent as the weight.

Now the experiments, made by means of concave *ſpecula*, are certainly well adapted for trying the truth of that theory with regard to the conſtitution of phyſical bodies, and the nature of thoſe moveable and commutable principles; for, if cold ſhall be found to be a moveable principle as well as heat, then will that theory be refuted; but if, on the other hand, this appearance of moveable cold ſhall actually be explained by the theory of the commutable principles of light and heat, as I have ventured to ſuppoſe, then will that theory be ſo far recommended to the conſideration of natural philoſophers.

In that theory, there is ſuppoſed to be, more or leſs, a continual emanation of light, whether viſible or inviſible, from bodies;

6

but, in this light, there are different ſpecies, both with reſpect to the power of giving viſion, and to that of exciting heat in bodies. It is principally the ſpecies of light which gives little viſion, in proportion to its power of exciting heat, that we have been now conſidering as predominant in the burning of combuſtible bodies, or a fire of coals. But now, upon the ſame principles, we may examine the other ſpecies of burning, in which the fire conſiſts of flame, and in which the predominant ſpecies of light is not the ſame with that of burning coal. We may thus have an opportunity of generaliſing the facts, which have been now inveſtigated with regard to fire or burning bodies.

SECTION II.

Inflammable Bodies examined, with regard to the nature of Burning.

IN examining the burning of combuſtible bodies, we took for an example a ſolid coal. This body, after being heated to incandeſcence, was expoſed to burn in atmoſpheric air; we then found that this coal, in burning, did not heat itſelf, but was ſoon cooled by the contact of the atmoſpheric fluid, and was thus extinguiſhed, merely for want of the neceſſary burning heat. It is now inflammable bodies which are to be examined with regard to burning; and, in this caſe, the flame of a lamp, *e. g.* may be thought to repreſent the ſingle burning coal, with which it may then be compared. But, before we can properly aſſimilate thoſe two things, there are many circumſtances to be conſidered.

This flame, no doubt, ſo far repreſents the burning coal, as being a body burning all over its ſurface expoſed to the atmoſpheric air. Thoſe two things are alſo ſo far ſimilar, as to be both continually communicating heat to the air in contact by which that heat is continually abſtracted. But they differ totally in this, that the coal, generating no heat in burning, is ſoon cooled and extinguiſhed; whereas the flame continues to burn, notwithſtanding all its ſurface is, like the coal, in contact with the cold atmoſphere by which its heat is continually abſtracted. Here is apparently an anomaly, or a thing which correſponds to neither of the two theories of fire which we have been now conſidering. For,

If, according to the antiphlogiſtic theory, we conſider this flame as burning like the inſulated coal, heated upon its ſurface by the oxigenating proceſs, or the *calorique* of vital air, How comes it that this heat is not diminiſhed, as in the coal, by the ſurrounding

ing fluid, more than it is heated by the burning? If, on the other hand, we ſhall conſider this flame as burning according to the theory which we have now inveſtigated, How comes this burning body to preſerve its heat, when the light, which is the immediate effect of burning, is emitted from the body, and radiated through the tranſparent atmoſphere, therefore cannot heat the body which is burning?

Here then it may be thought that our theory, with regard to the burning of combuſtible bodies, does not apply to that of inflammable bodies, ſo as to generaliſe thoſe phenomena. But, all theſe appearances will be properly explained in underſtanding the nature of flame, which is now the ſubject of inveſtigation.

We are here conſidering two different ſpecies of fire, viz. that of combuſtible and that of inflammable bodies; the general principle then ſhould be equally perceived in each. But, there muſt be ſpecialities in the caſe, ariſing from the different nature of the chymical ſubſtances employed; and, theſe ſpecialities may form a proper ſubject for inveſtigation, in order to illuſtrate the theory, and explain appearances.

The object to be held in view, on this occaſion, is the application of the principles, which we have acquired in the theory of combuſtion ſo far inveſtigated, to the burning of flame, in order to confirm our theory, and to explain the appearances of inflammation, as has now been done with regard to thoſe of combuſtion.

In the caſe of combuſtion, we have found, that the proper burning heat, of the kindled body, is not preſerved by the *calorique*, or condenſation of vital air; and we have found, that this heat, in the burning body, is entertained by the extrication of light, from the decompoſition of what may be called phlogiſton in the ſubſtance of the combuſtible body.

We are now to apply this doctrine to the fire of flame. But theſe two burning bodis, which are to be compared, differ extremely in their conſtitution, ſo far as the one is a ſolid body, of a ſubſtance which in relation to heat is extremely fixed, while the other is not only fluid, in oppoſition to hardneſs or concretion, but is an elaſtic fluid, which therefore is a moſt volatile ſubſtance. It is theſe two bodies which are now to be compared with regard to burning; and, as heat is a general principle or neceſſary condition for this chymical operation, we muſt firſt conſider thoſe two different kinds of bodies with regard to their affection by heat without burning.

In this reſpect, nothing can be more different than are thoſe two kinds of bodies. The one admits of being heated to incandeſcence; and, this is a neceſſary condition for its burning. The other is an elaſtic fluid, or a vapour, which is now to be conſidered with regard to incandeſcence.

In the chymical treatiſe upon the ſubject of phlogiſton, I have ſhewn that an elaſtic fluid, ſuch as the atmoſphere, may be heated above the degree of incandeſcence without emitting any ſenſible appearance of light. I then drew this concluſion, that the vapour of the inflammable ſubſtance was not heated to incandeſcence by the *calorique* of atmoſpheric air in burning; but, it was not then in my purpoſe, to give all the illuſtration to that propoſition, which we have now purſued with regard to combuſtion, and which we are at preſent applying to the caſe of flame.

Now, if an inflammable vapour be not capable of being heated to incandeſcence by the diffuſion of heat from incandeſcent bodies, and if ſome degree of incandeſcence be the proper condition for the burning of thoſe bodies, then, this inflammable vapour ſhould not be kindled, like a combuſtible body, by the communication of contact with an incandeſcent body. This reaſoning is alſo ſo far confirmed, in the caſe of certain extremely inflammable bodies, which cannot be kindled in that manner, but which are kindled moſt eaſily with the ſmalleſt ſpark of flame.

But, we are not here inquiring into the particular degrees of heat required as a condition for the burning of theſe two kinds of bodies, *i. e.* the combuſtible and the inflammable kind; nor are we to examine what may be the intenſity of the burning heat, or that which is a neceſſary condition for exciting flame in the kind of bodies now under conſideration. In the combuſtible kind, we have but one ſpecies of ſubſtance, which is a coal; but, in the inflammable kind, we have many ſpecies; and, theſe different ſubſtances require very different degrees of heat, in order to excite their inflammation.

Without inquiring therefore into the particular degree of heat, neceſſary to excite flame in the vapour which has the other neceſſary condition for burning, I am now to illuſtrate the general theory, That burning bodies are not heated by the *calorique* of vital air, and this I ſhall do from the manner in which inflammable bodies are kindled.

In the kindling of coals, the greateſt fire may be produced from the ſmalleſt ſpark, by properly diſpoſing bodies for that purpoſe, without which the burning will not proceed; but, in thus increaſing the quantity of fire or burning among bodies, there is required time, and a gradual progreſs, which may be conſidered as ſlow compared with what we ſhall find in the burning of flame. But this manner of kindling, in the burning of coals, has been perfectly explained upon this principle, that the immediate effect of burning is the emanation of light, and not the production of heat, as is ſuppoſed in the antiphlogiſtic theory of our chymical philoſophers. We are now to conſider how it may be with regard to the kindling of inflammable bodies.

There is nothing ſo different, in relation to light, as the two kinds of bodies now compared; for, the one is perfectly opake, and the other tranſparent. In the opake kind, it muſt appear to be impoſſible to propagate fire in any other but that ſlow manner, by the bodies mutually heating each other with their light emitted in conſequence of the burning; here is a progreſs therefore, which, though indefinite as to quantity if materials are not wanting, is extremely limited in point of celerity, as requiring a great quantity of time. But, the tranſparent bodies, which we are now examining, are not in this predicament of requiring any conſiderable time, but may be conceived as kindling with the greateſt rapidity, almoſt with that of light.

In order to underſtand this, we are to conſider the inflammable tranſparent vapou as conſiſting of an indefinite number of infinitely ſmall particles of inflammable matter, and we are to ſuppoſe each particle of the inflammable ſubſtance, upon the ſurface of the body, to be in contact with a particle of vital air, by which it is to burn as ſoon as the proper condition for that proceſs ſhall exiſt. Let now the ſmalleſt ſpark of flame be applied to one of thoſe particles, it is immediately kindled, and emits its light. This light immediately kindles theſe around, which emit their light, and thus propagate the flame. Now, what is here to limit the celerity of this propagation? Here is no opake bodies intervening to retard the progreſs of the light, in converting it into the burning heat neceſſary for the kindling of the ſolid body; each particle is inſtantaneouſly, as it were, lighted from the neighbouring ſpark or flame; and the accumulating light is propagated without any ſenſible loſs of time. In this manner, the fire may be conceived to run with the greateſt rapidity, from the one extreme of the greateſt body of inflammable vapour to the other, ſo that the whole ſhall be conſumed almoſt in a moment.

But ſuch an explanation cannot poſſibly be found in that theory which holds for principle, that the burning body is ſucceſſively heated to incandeſcence by the decompoſition of the elaſtic fluid of vital air; for, How could a great body of vapour be all heated, ſo as to burn, by the gradual communication of heat, which is not tranſmitted in the manner of light, but which muſt travel ſlowly through an extenſive body of this kind?

To ſee the impoſſibility of it being any ſpecies of heat, which in the decompoſition of phlogiſtic bodies produces fire, we have but to conſider a caſe which is moſt familiar to us. Let any inflammable ſubſtance be ſo heated as to boil or emit a column of riſing vapour; at the top of this column, however high it ſhall be raiſed, apply the ſmalleſt ſpark of flame ; the vapour then is kindled, and the flame deſcends in an inſtant from the top of the column to the ſurface of the inflammable ſubſtance which is thus kindled. Now it is impoſſible that the heating of a portion of the top of the column could deſcend in that manner againſt the ſtream of vapour continually riſing from the boiling fluid.

Therefore, in finding that fire is propagated with the greateſt rapidity through thoſe inflammable bodies, we ſhould have a confirmation of our theory, and an explanation of thoſe appearances. But, not only is the inflammation of a body of pure vapour, in contact with the atmoſpheric air, made in that rapid ſucceſſion which is inconſiſtent with the propagation of heat *, we

---

* We have a remarkable example, of the celerity with which flame is propagated, in that great Meteor which was ſeen, ſome years ago, from the one end of Britain to the other, and alſo in France. There can be no doubt, I think, that this was a ſtream of inflammable vapour

we ſtill have a more remarkable example of this rapid progreſs of fire, in the inflammation of thoſe vapours when mixed with the due proportion of vital air, which is required for decompoſing the phlogiſtic ſubſtance. In that caſe, there is an exploſion of the flame, which nothing but the rapid progreſs of light ſeems proper to explain.

Thus it is proved, that in flame, as well as in combuſtion, the immediate effect of the chymical decompoſition is not heat, but the extrication of the light which had been fixed in the phlogiſtic body.

We may now underſtand how the flame of a lamp or candle, which we at firſt compared to a ſolid coal burning in the atmoſphere,

---

vapour which had iſſued from the mineral regions of Iceland, at that time laid waſte with ſubterraneous eruptions. This train of inflammable vapour, about 60 miles high in the atmoſphere, had been kindled in the north end, probably by an electrical ſpark; the inflammation then run the ſpace of ſeveral hundred miles in, perhaps, a minute of time, or little more.

ſphere, continues to burn, while the coal is neceſſarily extinguiſhed. This flame cannot be compared, in this reſpect, with a burning coal; for, that flame properly repreſents a fire burning by the conſtant acceſſion of phlogiſtic bodies to be kindled in ſucceſſion, and by the propagation of its heat among thoſe bodies from the commutation of its light. So far therefore as this inflammable vapour continues to be produced from the heated body in a conſtant ſucceſſion, and the inflammation propagated by continual kindling of thoſe advancing particles, this burning proceſs is properly aſſimilated with a fire of coals, when this is preſerved by the continual addition of combuſtible materials.

We may now explain an appearance which is continually occurring in the burning of vegetable or animal bodies; this is, the fuliginous ſmoke of thoſe fires, and the very different quantity of flame that may be made to appear, by burning thoſe bodies in different circumſtances.

Animal and vegetable bodies are neceſſarily compoſed of both kinds of burning ſubſtances, that is, of combuſtible and inflammable ſubſtances, but, beſides thoſe pure combuſtible and inflammable ſubſtances, animal and vegetable bodies contain a great deal of aqueous ſubſtance, which is neither inflammable nor combuſtible, but which is evaporated by a heat much inferior to that which is neceſſary for burning. Therefore, when we expoſe ſuch a body to a burning heat, inſtead of kindling, the aqueous part is evaporated, and along with it the volatile or inflammable ſubſtance, which immediately condenſes in mixing with the cooler atmoſphere, thus forming ſmoke; and this ſmoke may be either more oily or more fuliginous according to the quality of the ſubſtances, and the degree of heat which the vapour had ſuſtained, the difference, in this caſe, being the greater or leſſer degree of inſpiſſation that the oil had ſuffered, or the greater or leſſer proportion of coal which is in the ſubſtance of the ſmoke. But this oleaginous and fuliginous vapour cannot be made to burn ſo long as there is mixed with it a ſufficient quantity of the aqueous vapour, which is heated only 212 degrees in general; for it requires many hundred degrees more to kindle the oil.

This leads us to conſider the means that may be uſed for procuring from thoſe compound bodies, the greateſt quantity of combuſtion with the ſmalleſt quantity of flame, in burning.

If we expoſe theſe bodies to a gradually increaſed heat, without the application of vital air to make them burn, *i. e.* in diſtilling thoſe bodies, in cloſs veſſels, we firſt ſeparate moſt of the aqueous ſubſtances, and then moſt of the ſubſtance which is oily or inflammable; what then remains is the coal which is combuſtible, and all the inflammable part is ſeparated without burning. Now ſomething of the ſame kind may be done by the artificial regulation of the heat, in burning thoſe bodies expoſed to the atmoſphere, in which caſe they will appear to burn without flame.

In order to ſee this, let us take thoſe bodies after the moſt part of their aqueous ſubſtance is evaporated, and but little of their oil. Here let us apply ſuch a heat as ſhall ſuffice to make the coally ſubſtance burn, which is the heat of incandeſcence. But, this heat, though ſufficient to evaporate the oil, has not light ſufficient to kindle that inflammable vapour; conſequently, by properly managing that fire, we ſhall be able gradually to burn all the coal, and to evaporate all the oil without kindling it. The inflammable vapour, which is thus produced, is only to be kindled by increaſing the burning heat of the coal, or the light which it emits, to that degree of incandeſcence which is neceſſary to kindle the ſmalleſt portion of the oily vapour, when the inflammation will ſuddenly commence. Thus we have perhaps all the phenomena of fire and ſmoke, which appear in the burning of animal and vegetable bodies, properly explained.

In the chymical diſſertation upon phlogiſton, when examining that cardinal experiment of burning inflammable and vital airs, I endeavoured to confute the theory of *calorique* by an argument taken from the quantity of fire produced on that occaſion; at preſent, I have drawn the ſame concluſion, by conſidering the celerity with which the inflammation is produced. Thus we find, that neither the quantity of the fire, nor the velocity of its propagation, correſpond in any degree with burning being the effect of heat, but that, on the contrary, every appearance proves the heat to be the conſequence of light which is extricated on theſe occaſions.

We have now other phenomena to conſider, as we are to examine the burning of bodies under particular circumſtances.

SECTION

SECTION III.

Of Deflagration, Exploſion, and Fulmination in Burning Bodies.

WE have been examining the burning of bodies in atmoſpheric air, when in its elaſtic fluid ſtate; but, this oxigenating ſubſtance is alſo found in a ſolid concreted ſtate, as in nitre, and in the ſuper-oxigenated marine acid. Having thus a powerful oxigenating ſaline ſubſtance, we may now compare the burning of bodies when decompoſed with nitre, inſtead of atmoſpheric air which we have already conſidered.

For this purpoſe, we are to conſider the deflagration of nitre, firſt, with the combuſtible ſpecies of burning bodies, (of which charcoal is the example), and, ſecondly, with the inflammable ſpecies, (of which ſulphur will be the example); this then will give us a proper view of that ſpecies of burning, and of the circumſtances with which it is attended.

In the examples of charcoal and nitre, which are to be mixed together for that ſpecies of burning which is called deflagration, we may firſt conſider the chymical conſtitution of the two ſubſtances which we are thus to employ, in order to have a proper notion of all the parts which are then to come into action, and which are mutually to affect each other in that burning proceſs, which may be conſidered as a chymical decompoſition by means of a double elective action.

In the ſubſtance of charcoal, after abſtracting from a ſmall quantity of inflammable compoſition which is ſtill left in the coal, and alſo neglecting that ſmall quantity of earthy matter which is neceſſarily in its compoſition, we have ſtill a compound ſubſtance as the ſubject of our experiment. The one part of this ſubſtance is that to which may be properly given the name of phlogiſton ; and, of this ſubſtance, we ſo far know the nature, negatively, as having no weight, or not affecting the gravitation of the body, ſo far as we know.

The other part may perhaps be conſidered as a much more palpable thing, of which we then may underſtand the poſitive qualities. This however, I believe, is a miſtake ; we do not perhaps know more of the one than of the other. While thoſe two things are united, we know nothing of the ſpecific qualities of either ; it is the compound quality, of this aſſociated ſubſtance, that we perceive in coal. For, though the weight of the body is a poſitive quality that may be properly attributed to the one part alone, we have as good reaſon to attribute the poſitive quality of blackneſs or opacity, as well as the power of conducting electricity, to the other *.—

There

---

* See Diſſertations upon Subjects of Natural Philoſophy.

There is no reaſon, therefore, to ſuppoſe that we are better or more poſitively informed, with regard to the nature of the one of thoſe two conſtituent parts of charcoal than of the other; and, we are to have recourſe to the examination of thoſe two ſubſtances when ſeparated from each other, in order to know more of their nature.

But here, again, we meet with the ſame or ſimilar difficulties; for, the one of thoſe ſubſtances is a fugacious thing, and it only gives us information of its nature by its eſcape, unleſs we ſhall conſider the information of our ſight, on this occaſion, as being the moſt abſolute information. This is the proper phlogiſtic part; and, though this ſenſation of light does not give us information with regard to the ſtate of that phlogiſtic ſubſtance, when united in the body, it aſcertains it to be that ſame ſubſtance which is continually flowing to us from the ſun; therefore, the fugacious nature,

ture, of this ſolar ſubſtance, is no objection to its being eſteemed a ſubſtance at leaſt as well known as any other.

On the other hand, the permanent nature of the other conſtituent part of charcoal, which after ſeparation we have it in our power to confine, leads not to any more perfect knowledge of its proper nature; for, here we ſtill have it in a compound ſtate; and, it is only now combined with a different ſubſtance. This is the elaſtic fluid which Dr Black firſt named fixed air, and which he diſcovered as the ſubſtance ſaturating alkaline earths and ſalts; but now this compound ſubſtance is moſt ſcientifically named the carbonic acid, which it truly is, in having been oxigenated by the combination of vital air.

Hence all our knowledge, with regard to the nature of charcoal, comes to this, that it is compoſed, on the one hand, of the ſolar ſubſtance which does not gravitate, and, on the other, of that vegetable principle which, being oxigenated or combined with vital air, forms carbonic acid, or that elaſtic fluid which is found ſo abundantly in this earth ſaturating calcareous ſubſtances.

The chymical nature of nitre, again, is ſo far underſtood as being compoſed of an acid and a fixed alkaline ſalt. The acid, with which we are here principally concerned, is known to be compoſed in part of vital air, or to contain that oxigenating ſubſtance in a large proportion.

Having now to decompoſe this chymical body, charcoal, by means of the oxigenating ſubſtance contained in the nitrous acid, nitre and charcoal are to be united, and then kindled. In that caſe, fire and a moſt violent exploſion take place. This fire is now to be compared with that of the coal burning with atmoſpheric air.

We have ſeen that a coal, burning with atmoſpheric air, exhibits a very different appearance, according as it is more or leſs of a ſolid body; but here, where we may have the charcoal intimately mixed with the oxigenating or decompoſing ſubſtance, we might expect to find the decompoſition or burning to proceed with great rapidity, and the light thus diſengaged to become moſt bright. Now it is in the laſt of theſe that we may perhaps find our expectations in ſome meaſure diſappointed; and, this is the appearance which we may now endeavour to explain.

In the burning of charcoal by means of nitre, there are two diſtinct operations to be conſidered. One of theſe is the diſengagement of the ſolar ſubſtance, which ſhould then appear in its proper form of light; the other again is the production of a carbonic gas by combination of the oxigenating principle with that part of the coal, which is now deprived of its phlogiſton. But, this laſt operation muſt require much latent heat, in order to make it, from a concreted ſubſtance, (which is was, both in the nitre and in the coal,) become an elaſtic fluid body; and, this heat muſt be procured from the commutability of light, which is abundantly produced on this occaſion. Hence we may underſtand how the naſcent light may be much impaired, in expanding the gas which is generating in that operation; and therefore that there ſhould appear leſs light, than might otherwiſe be expected from the conſumption of the coal. At the ſame time, there ſhould be an elaſtic exploſion, from theſe two fixed ſubſtances, which, in this commutation of naſcent light and latent or elaſtic heat, finds its true or only explanation.

Here is a theory the truth of which may now be tried, by comparing with it the deflagration of nitre and ſulphur; for, here are different circumſtances of things, conſequently, there ſhould follow different appearances;

pearances; and if, in this caſe alſo, the appearances ſhall correſpond with the principles upon which we have reaſoned, the theory of this deflagration, as well as that of ſimple burning, will be ſo far confirmed.

In the deflagration of ſulphur, while the phlogiſtic part eſcapes in light, the proper ſulphuric matter is oxigenated by the condenſed vital air of the nitrous acid; and, this vitriolic acid is combined with the alkaline baſe of the nitre. Here then is not required the commutation of the naſcent light, as in the caſe of coal; and, the rapid inflammation of this volatile ſubſtance muſt afford the production of moſt intenſe light.

Now in order to ſee the juſtneſs of this concluſion, we have but to conſider, that, according to the principles upon which we reaſon, ſulphur may be burned either in the ſloweſt manner and with a ſmall flame, when moſt of the naſcent light is extinguiſhed in expanding or heating the contiguous atmoſpheric ſubſtance; or, it may be burned with the greateſt intenſity of inflammation: In the one caſe, the light, from the burning ſulphur, is not fit almoſt to illuminate bodies, but is extremely coloured the little that appears; in the other caſe, the light is moſt vivid, and ſo far deſtitute of colour, or approaching to the perfect light. But between theſe two extremes, we have a great range of degrees, in which the ſulphur may be burned with a light which ſhall approach more or leſs to either of thoſe extremes; and, all this proceeds upon the ſame principles.

Thus we have generaliſed the deflagration of bodies, according to the principles of fire or burning; but ſtill we have a more violent caſe of deflagration to conſider; and, this ſpecies of burning we may term the fire of exploſion.

After explaining the two laſt caſes of deflagration, this of exploſion will not be difficult to underſtand; for, it is only a compoſition of the other two. We have therefore now only to examine, what ſhould be the conſequence of uniting together thoſe two caſes in the ſame operation.

In order to do this, we muſt conſider, that, in the one caſe, there was a great production of elaſtic fluid without great intenſity of light or heat, and that, in the other caſe, there was a great production of intenſe light but no great production of elaſtic vapour.

But this is not all, we are alſo to conſider, that, in the deflagration of coal, the proceſs of burning is ſlow compared with the deflagration of the inflammable body. But now let us ſuppoſe the rapid inflammation of the ſulphur, and its bright light, to be diſperſed intimately among the maſs of the opake ſlow burning coal, and we ſhall find, that, ſo far as the intenſity of the light and the celerity of the deflagration is thus amazingly increaſed, the conſequence muſt be, the ſudden production of the moſt powerful elaſtic fluid, expanding with extreme force.

Thus we find the phenomena of gunpowder fully explained, according to the general theory of deflagration, and the particular circumſtances or compoſition of this exploding powder.—But there is ſtill another caſe to be conſidered, in which we ſhall find occaſion to employ our principles ſo far inveſtigated, and to explain the actual appearances of things.

When coal is deflagrated with nitre, although this exhibits a rapid ſpecies of burning, compared with a ſolid coal expoſed to atmoſpheric air, it is a gradual and ſlow operation, compared with the mixture of ſulphur and nitre which deflagrates rapidly. —In forming again the exploding powder by the compoſition of thoſe two kinds of deflagration, we obtain an extremely powerful expanſive force, in the elaſtic fluid that is formed, ſo as to be capable of overcoming a moſt amazing reſiſtance; but, the celerity of this expanſion, however great compared with the gradual deflagration of the coal and nitre, is far from inſtantaneous, and may be ſlow in compariſon of an exploſion which ſhould be phyſically inſtantaneous, that is to ſay, apparently ſo. Let us now endeavour to form an idea of what this would require.

In exploding gun-powder, a ſpark of fire is applied to one place of the maſs, and, with a rapid progreſſion, it is ſoon communicated to the whole; but, we may conceive every particle of the maſs to be, by an increaſed heat, ſo prepared for burning, that the inſtant one of them is kindled all the reſt ſhall explode at once, without waiting for the gradual progreſſion from particle to particle, which naturally takes place in the employment of this powder. Now, Is there ſuch a thing to be found in nature, or in art?—It muſt be evident, that were gun-powder ſuch a ſubſtance as might be melted altogether, or brought by heat into a fluid ſtate, then, by gradually increaſing that heat, the whole maſs might be brought to that ſtate of deflagration which we require, in order to have the inſtantaneous exploſion.

Now, we have actually ſuch a compoſition as this; for, inſtead of compounding gun-powder with charcoal, which is to produce the elaſtic power required for the purpoſe of that exploſion, we may ſupply its place with an alkaline ſalt ſaturated with fixed air or carbonic acid.—In juſtly proportioning thoſe three things ſulphur, nitre, and aerated fixed alkaline ſalt, and by melting together this compoſition, we obtain a fluid which, by properly increaſing the heat, comes at laſt to that point when the decompoſition takes place at once, apparently, in every particle of the maſs. This is the very thing which we required; and thus is actually procured a proper fulminating compoſition, which ſeems to be the ultimate to which we may proceed.

In the exploding powder, it is the force of the elaſtic fluid produced that forms the proper character of this powder, which kindles with the ſmalleſt ſpark, and thus gives a power which is much employed for the purpoſes of man. But, in the fulminating compoſition, it is not the power of the exploſion which forms the character of this operation; it is the celerity with which that exploſive power is formed. It is thus that a violent percuſſion of the air, without any confinement or mechanical contrivance, produces the ſound of muſketry, or cannon, in the burning of this fulminating compoſition.

There is now a circumſtance to be obſerved in this fulminating operation, which, in being explained, will contribute to confirm the theory.

In the compoſition of this fulminating ſubſtance, there is a certain quantity of ſulphur and nitre, which, in deflagrating, we know produces the brighteſt flame; but here, though the burning of the ſulphur be almoſt inſtantaneous, yet very little light appears in the fire of that exploſion; and, this is the appearance that ought to be explained.

To underſtand this phenomenon, we have only to conſider what difference the mixture of the aerated alkali makes in the operation. Without the alkali, the deflagration of the ſulphur and nitre would be made with much light, as has already been explained; but, in this fulminating compoſition, the naſcent light is almoſt all employed in giving the heat of elaſticity to the carbonic acid, or fixed air, which thus ſuddenly expanding, is the proper cauſe of fulmination. Thus, according to our theory, fulmination, in this caſe, is properly the noiſe of that rapid exploſion, without the proper light of the deflagration.

This theory of fulmination may be illuſtrated by that which happens with regard to the fulminating preparation of gold. Aurum fulminans may be heated to a certain degree without exploding; but if, after cooling again, one grain of this powder ſhall be bruiſed, the whole explodes without being heated. Here it is evident, that the fulmination, however apparently inſtantaneous, is ſucceſſive, the exploding of one part being the cauſe for the exploding of another.

It was not till after writing this diſſertation, that I have ſeen an account of very intereſting experiments, by Dr Deimen and his coadjutors, (*Recherches Phyſico-Chemiques*). This is the burning of ſulphur with ſome of the metals, without the aid of vital or atmoſpheric air. It is ſurpriſing that this experiment or fact ſhould have been ſo long unknown; but, when we conſider, that it is the contention between the phlogiſtic and the antiphlogiſtic theories of burning that renders this experiment ſo intereſting, we ſhall be inclined to believe, that the fact may have been often obſerved, without being conſidered as of any importance. The preſent ſtate of ſcience, with regard to that ſubject, makes this experiment moſt valuable, when otherwiſe it would be but an inſulated fact. I may now avail myſelf of this new light, in forming an argument in favour of the phlogiſtic doctrine.

The antiphlogiſtic theory maintains, that ſulphur and metals are ſimple ſubſtances, or to us uncompounded bodies; and that, in the burning of the one, and calcining of the other, the oxigenating part of vital air is combined with thoſe ſimple ſubſtances, while the *calorique* of the vital air, thus ſet at liberty, exhibits the appearance of fire or burning. This doctrine is plainly refuted by theſe experiments, where the phlogiſtic part is made to appear in flame, without the *calorique* of vital air, and without the oxigenating proceſs. Here the burning operation is performed by means of heat and the union or combination of the ſulphuric and metallic ſubſtance; the compoſition ſeemingly requiring or admitting of leſs phlogiſton, than in the ſeparate ſtate.

Here is a new ſpecies of burning, ſo far as the oxigenating part of vital air, which ſeems to be required in all the other proceſſes of this kind that we know of, is not neceſſary in this caſe. In other reſpects, I ſee no reaſon why this example ſhould not be comprehended in the phlogiſtic theory of fire or burning.

SECTION IV.

Of the Emiſſion of Coloured Light from Burning Bodies.

We have aſſimilated the two different kinds of burning bodies, in the operation of fire; and we thus have generaliſed the principle of burning, in appealing to matter of fact, or natural appearances properly analyſed.

We have alſo applied this theory for explaining the various appearances of deflagration, exploſion, and fulmination, in the compoſitions of known ſubſtances. We are now to endeavour to inveſtigate ſome of the particular affections of the ſeveral ſpecies of light, in being emitted from thoſe different kinds of burning bodies.

All hard or concreted bodies are capable of being heated to the ſtate of incandeſcence; in which caſe, the light emitted, when the heat is in a low degree, is always of the red ſpecies; and, in proportion as they are more intenſely heated, the light which they emit is more and more of the compound ſpecies, in approaching to the white colour.

With regard, again, to melted bodies, or thoſe that are ſimply fluid, theſe, ſo far as heated to incandeſcence, emit light upon the ſame principle; but it is by no means certain, that all thoſe bodies may be heated ſo as to emit light. I am almoſt of opinion, that, without ſome principle or degree of concretion, opacity, or colour, in the ſubſtance of thoſe bodies, they would not emit light, or are not capable of being put into the ſtate of incandeſcence; this, however, is not a point which we are concerned in determining; therefore, I only throw out this opinion as a ſubject proper to excite the inquiry of natural philoſophers.

The inflammable bodies, which we are now examining, muſt be conſidered as not admitting of that ſtate of incandeſcence by means of being heated, or as not emitting light upon that principle; for, they are elaſtic fluids, which cannot be ſo heated. The only principle, upon which we are to acknowledge them as emitting light, is that of burning. Here then a queſtion occurs, with regard to the ſpecies of light which thoſe bodies ſhould emit, in the loweſt intenſity or degree of burning.

It muſt appear, that we have no principle or data for determining, *a priori*, the ſpecies of light which ſhould be then emitted, although there may be reaſon to conclude, that this coloured ſpecies ſhould be different from that which is emitted by the coal. For, ſo far as light is to be affected by the ſpecific difference of the bodies with which it is to have an action and reaction, we have no reaſon to ſuppoſe that light ſhould be affected in the ſame manner by bodies, the conſtitutions of which are ſo extremely different. That the ſeveral ſpecies of light are variouſly affected by the different conſtitutions of bodies, is a fact in natural philoſophy which requires no illuſtration. We have but to reflect upon the powers in bodies for variouſly reflecting, abſorbing, tranſmitting, and refracting light, beſides the partial affections of the different ſpecies, in being variouſly detained in thoſe affections, and thus divided into colours. The only *general*, therefore, which we may form in relation to that ſubject, is this, that the ſeveral ſpecies of light ſhould be differently affected, according to every material change which takes place in the conſtitution of bodies.

But the two kinds of bodies now conſidered are ſo extremely different in their conſtitution, although agreeing in being phlogiſtic bodies, that, ſo far as this is to operate in the rule of emiſſion for the different ſpecies of light in burning, we ſhould conclude a different rule to be obſerved in thoſe two caſes. We could not ſay that the rule of emiſſion for the different ſpecies ſhould be reverſed in thoſe two caſes; but, in finding the rule actually reverſed, we have a right to ſay, that this muſt be the effect of the different conſtitution of thoſe burning bodies, and the various affection of the ſeveral ſpecies of light.

It appears from experience, that there is a general rule obſerved for opake, concreted, and combuſtible bodies emitting light in the loweſt degree of incandeſcence, or burning; and, this rule is, that the red ſpecies ſhall be then emitted; now, in the oppoſite kind of bodies, we find the rule reverſed, and that the ſpecies of light moſt oppoſite in the priſmatic ſcale is then emitted. Thus we find, that the blue or violet ſpecies is always emitted on thoſe occaſions.

In the flame, for example, of a candle, the light abſorbed, in contact with the cold atmoſpheric air which is thus heated, muſt be of the red ſpecies; for, the weak light, remaining or emitted in the under part of the flame, is blue. That the light is thus abſtracted from the under part of the flame, in heating the atmoſpheric fluid which is conſtantly riſing up along the flame, appears from this; a concreted body, placed vertically above the flame, is heated to incandeſcence by that riſing ſtream, although that expanded and heated fluid does not itſelf emit light.

In the upper part, again, of the flame, there is often a degree of redneſs in the light which appears; and this happens more or leſs according to the quality of the ſubſtance which is burning, and according to the conditions of the burning, in being leſs or more properly ſupplied with vital air. But, all this is perfectly explained from the coally ſubſtance contained in the inflammable body, which carbonic matter may be more or leſs conſumed before it reaches to the upper part of the flame; where alſo it may be made to appear in a fuliginous ſtate, without being burned.

If the intenſity of fire be much diminiſhed by the aqueous matter in the inflammable vapour, the general colour of the flame will be blue, as we may obſerve in the burning of ardent ſpirit.

A queſtion may perhaps here naturally occur, viz. How comes the ſame atmoſpheric air, which is employed in burning, to affect the emerging light ſo differently in thoſe two caſes, of ſolids, and elaſtic fluids? We are not now inquiring what may be the cauſe of this diverſity of colour in thoſe two ſpecies of burning bodies; it is an elective action of light in relation to bodies; and theſe elective actions are matters of fact, which do not admit of farther explanation. But, we generaliſe this matter of fact in relation to the elective action of light, in finding that the general colour of all ſolid or opake bodies, when in the loweſt ſtate of incandeſcence, is that of redneſs, or that in which the red ſpecies of light prevails. Now, could we know the colour of the incandeſcent heat, in like manner, of elaſtic fluids, we might then either generaliſe that elective action of light, which we diſcover in ſolid bodies; or, we ſhould diſcover another elective action of the light, in relation to elaſtic fluids. But, we cannot heat elaſtic fluids to incandeſcence; and, in thoſe burning fluids, it is the oppoſite ſpecies to the red which appears as proper to the flame, when ſufficiently diminiſhed in its incandeſcence. This then is the fact which we have now generaliſed with regard to inflammable bodies, in like manner as has been done with reſpect to the light emitted from incandeſcent and combuſtible bodies *.

Theſe are the general phenomena of flame; and theſe may be obſerved not only in the flame which burns with great intenſity,

---

* We are not here concerned with the intermediate ſpecies of the priſmatic colours, which are occaſionally perceived in the flame of bodies containing particular chymical ſubſtances, by which the naſcent light is affected out of the ordinary or general courſe; this is a caſe ſimilar to that of the colouring modifications of matter in bodies, by which particular ſpecies, of the incident or tranſmitted light of the ſun, are abſorbed and retained, while the other ſpecies proceed to inform our ſenſe with their peculiar colour.—Vide Diſſert. upon Subjects of Nat. Phil. Diſſ. VII. C. V.

tenſity, and thus produces much light, and conſequently heat, but alſo in thoſe which burn with ſo little intenſity as to be hardly capable of producing ſenſible heat. An example of this we find in the burning of phoſphorus, by ſimple expoſition to atmoſpheric air; we have but to examine this flame with a magnifying glaſs, and we perceive in it all the phenomena of which we have here been treating.

But there is ſtill a farther illuſtration of this ſubject of fire which I think of great importance to conſider. This we have in electricity, which is diſtinctly different from both light and heat, although it ſtands in a cloſe relation to both; and now this ſubject is to be examined, with regard to the phenomena of burning which is here exhibited.

It is not in the ſtate of equilibrium that electricity exhibits any appearance of either light or heat; but, in the violent exertions of this fluid to reſtore an equilibrium which had been greatly violated, we find appearances which may be generaliſed with thoſe of fire, and which will thus ſerve in ſome meaſure to illuſtrate the theory of burning.

The electrical fluid, in this ſtate of tranſition, is either made to paſs through the ſubſtance of an opake conducting body, or it is made to leap from one conducting body to another, through a ſhort ſpace, without any ſenſible intermede, or through a rare tranſparent fluid; and it is in this ſtate of tranſition that it exhibits to us the appearances of fire.

In the caſe of being conducted through an opake body, it exhibits the appearance of heating the body from the loweſt to the higheſt degree of incandeſcence; but, on this occaſion, it is impoſſible to ſay whether this active ſubſtance emerges immediately in the ſtate of light or heat; for, as thoſe two things are mutually convertible, the appearance muſt be the ſame to us; whether, as light within the ſubſtance of the body, it heats it; or whether, as heat, the body is thereby made to radiate or emit light.

But, this is not the caſe, when the electricity is made to leap from one conducting body to another, through the rareſt ſpace, or through a fluid which we have already found to be incapable of being heated to incandeſcence. Here, the commutable ſubſtance of electricity is immediately converted into light; and, in this ſtate, it exhibits the ſame appearance which is found in flame; conſequently, there is reaſon to conclude, that the converſion of electricity, into the appearance of fire, is made upon the ſame principle as that by which bodies are made to burn.

But here we have an opportunity of adding confirmation to this theory. For, beſides that inſtantaneous tranſition which is made in leaping from one conducting body to another, the electric fluid may be made to flow in a conſtant ſtream; and this exhibits, in a great degree, the caſe of inflammable bodies emitting their light in flame. Here we have an opportunity of examining the appearance of this electric flame; and, it is here that the ſame order is obſerved, for the emiſſion of the different ſpecies of light. Thus the theory of fire or burning bodies is illuſtrated and confirmed in the appearances of electricity, when this moving ſubſtance is made to change its modification in being converted into light.

SECTION V.

Recapitulation and Concluſion.

THE moſt perfect light, ſuch as comes to us from the ſun, being white, is known to be compoſed of different ſpecies, which in relation to our ſenſe are properly coloured. Theſe ſpecies are variouſly affected by the different kinds of bodies on which they fall; and are thus more or leſs reflected, extinguiſhed, inflected, tranſmitted, and refracted. Theſe ſpecies have alſo different powers for affecting our ſenſe, and for heating bodies. It is thus that we have now formed the diſtinction of two very different kinds of light; the one having great luminating power, for the ſenſe of ſight, while it has comparatively little power in exciting heat; the other having, on the contrary, heating power, while it excites no viſion.

It is the light of burning bodies which has been thus inveſtigated, as conſiſting of theſe different kinds; and, we have been examining the principle of fire, or nature of burning. We may now briefly ſtate what we have found in relation to that ſubject.

Firſt, we have found reaſon to conclude, that in no caſe of burning is the light, which then appears, the effect of heat obtained from the decompoſition of vital air; but that it is the extrication of light, fire, or phlogiſton, which had ſubſiſted in thoſe bodies as fixed light, or a peculiar modification of the ſolar ſubſtance, combined with the other chymical elements, or with the gravitating matter of the body. This then is a diſtinct modification, different from thoſe of heat, or light, or electricity. Hence we obtain a theory of burning bodies, or a principle of fire, diſtinctly different from that of heat.

Secondly, we have found burning bodies to conſiſt of two kinds; the one of theſe is properly combuſtible, the other is inflammable. But, though the phenomena of burning, in thoſe two caſes, are extremely different, we have found reaſon to conclude that they both proceed upon the ſame principle. Here then is a generaliſation of the ſubject, which is to ſcience of great importance.

Thus, it is light which is the thing immediately produced in burning; and, it is only mediately that heat is excited on this occaſion; either, in thoſe combuſtible bodies which are burning in an aſſociated ſtate, *i. e.* a fire of coals, or, in the inflammable ſpecies, where the emerging light heats both the inflammable body and the contiguous atmoſpheric fluid.

Thirdly, in conſidering the proceſs of burning as an inſtantaneous thing, ſeeing that we have no knowledge of the particular ſteps which may ſucceſſively take place, we neceſſarily connect, with that ideal point, two periods of time; the one immediately prior, and the other poſterior, to that moment of change. In the firſt, *i. e.* before burning, there muſt be formed a proper ſtate of preparation, when all the neceſſary conditions for the complicated chymical operation muſt take place; in the laſt again, *i. e.* after burning, there is a new ſtate of things, which is the effect of the momentary operation.

ration. Now it is in comparing thoſe two ſtates, which we examine, that we judge of what muſt have happened, or been tranſacted, in the intervening period, however inſtantaneous.

But, beſides that ſuppoſed inſtantaneous operation, in which the decompoſition of phlogiſton and the oxigenating compoſition of vital air are made, we have another ſubject for conſideration; this is the communicating of that fire or burning proceſs, from the firſt ſpark or kindling, ſucceſſively among the individual parts of the body which is thus to be conſumed. Now, this propagation of fire through the maſs, may be executed or proceed in very different portions of time, or with more or leſs celerity, according to the circumſtances which variouſly influence that operation; and this exhibits very different appearances, which have been explained.

It is in this manner that I have diſtinguiſhed,

guiſhed, firſt, the ſimple burning of combuſtible and inflammable bodies, by the application of atmoſpheric air. Secondly, I have conſidered the burning of thoſe bodies by the application of vital air in a concrete ſtate, when it can have no latent heat; and this has been diſtinguiſhed by the term of *deflagration*. Thirdly, I have conſidered the compoſition of the combuſtible and inflammable ſpecies, when united together and burning with the concreted air; this then forms another ſpecies of deflagration, which has here been termed *exploſion*. Laſtly, I have conſidered a ſtill more rapid progreſs of the burning, or propagation of the fire throughout the decompoſing maſs; and this forms another ſpecies of exploſion, which has been termed *fulmination*. It is by ſhowing the proper circumſtances which, in thoſe different caſes, occaſion the more or leſs rapid progreſs of the burning through the maſs, that I have endeavoured to explain the various appearances, and to generaliſe the proceſs of fire or burning, in order ſo far to complete the theory.

Fourthly, during that period of burning, which is variouſly performed as to time, we have ſeen that there is occaſionally a diviſion made of the naſcent light; one part being extinguiſhed in heating or expanding the contiguous elaſtic fluid; while the other continues to proceed as light emerging from the burning body. It is in this manner that, by diminiſhing ſufficiently the ſize of the flame, almoſt all the naſcent or emerging light is extinguiſhed in heating the contiguous fluid, and little remains for propagating the fire, and for illuminating the ſurrounding bodies. Thus alſo, on the contrary, by feeding the fire with the pure oxigenating fluid, the fire becomes more bright, and the conſumption of the phlogiſtic body is increaſed.

Laſtly, there is a certain general rule obſerved with regard to the production of coloured light, in thoſe two caſes of combuſtible and inflammable bodies. In the firſt, it is the one extreme of the priſmatic order which is made to prevail in the colour of the diminiſhed light; whereas in the ſecond, it is the oppoſite extreme which then appears. We thus may underſtand that, in the burning of coals, it is the blue ſpecies of light which is extinguiſhed in heating the atmoſpheric fluid; and that thus the red ſpecies appears to prevail in the light of that fire. Whereas, on the other hand, it is the red ſpecies which is extinguiſhed in flame; conſequently, it is the blue ſpecies which then occaſionally appears, as the colour of that part of the flame which is diminiſhed in its light.

Here then is a generaliſation of many facts reſpecting light and heat, by reaſoning from effect to cauſe. It will thus appear, that thoſe two commutable principles, light and heat, form one of the great agents in the material univerſe; and that this agent is diſtinctly different from gravitation and concretion, the two modifications of another great agent,—modifications by which bodies are always heavy, and occaſionally hard. Now it is the buſineſs of philoſophy to explore the general laws by which all the particular actions or events, belonging to thoſe powerful agents, are ſo wiſely governed. It is thus that philoſophy enables man to ſee the intention of his Author, by reading that which is written in the book of nature.

May I be allowed to add, that here are, for the conſideration of philoſophers, two very different theories with regard to the actions and affections of light and heat,—theories by which the appearances of nature ought to be explained. If, on the one hand, the theory of *calorique* ſhall be adopted, then, it will be neceſſary to give ſome more explicit idea of the ſubject; for, the well known principle of *latent heat*, (from which the notion of that theory was taken,) however important in natural philoſophy, will not explain the appearances of fire. If, on the other hand, the theory of phlogiſton and inviſible light, as has been now explained, ſhall be approved of, then, philoſophers will find it neceſſary to acknowledge another kind of matter in bodies, beſides that which poſſeſſes the power of gravitation and concretion.

But this opens a great field for philoſophy, in which we ſhould ſee the cauſe of fluidity and expanſion, as well as the proper diſtinction of concretion and gravitation. Philoſophy will thus acquire a general principle of ſeparation and repulſion, as well as a general principle of union or attraction. Gravitation will not then be the only univerſal principle in the ſcience of phyſics; although it is only by means of that firſt great principle of attraction that the principle of repulſion may be properly eſtabliſhed, as being inveſtigated both in its direction and intenſity. I have made an attempt of this kind, in *Diſſertations upon Subjects of Natural Philoſophy;* with what ſucceſs remains to be determined by natural philoſophers.

PART VI.

Fixed Light, or the Principle of Fire, examined with regard to Gravitation and Inertia.

SECTION I.

The Solar Subſtance examined with regard to Gravitation.

WHEN treating of abſolute gravity *, or the principles of real weight in bodies, I conſidered the material univerſe as compoſed of two different ſubſtances, acting with oppoſite intentions or directions, and mutually reſiſting the accompliſhment of each others actions. Upon this principle I ſhowed, ed, That we have no certainty for concluding the weight of bodies to be a juſt meaſure of the abſolute quantity of the matter, or ſubſtance, which acts upon uniting principles in thoſe bodies; but that it may only indicate the quantity of gravitation which is then not oppoſed and balanced by the ſeparating power,—a power which is as general in the univerſe, perhaps, as that by which bodies tend continually to unite. Here then would be a principle of levity, by which bodies might be affected, as well as a principle of gravity. But now the queſtion is, If there be ſuch a principle, by which the actual weight of bodies is truly affected?

---

* Diſſertations on Subjects of Natural Philoſophy.

Upon no occaſion is there ſo much reaſon to look for the operation of this principle of levity, as in the burning of phlogiſtic bodies; for, ſo much of the ſolar ſubſtance is ſeparated from a body in burning, that this ſubſtance, conſidered as a principle of levity, might have ſenſibly affected the gravitation of the body when combined with it. We are therefore to inquire how far this may be made actually to appear.

Burning bodies have been accurately examined by philoſophers of late; for, in the new diſcovery of having water produced by burning inflammable and vital air in cloſs veſſels, they had occaſion to examine how far the weight of the water was equal to that of the materials from whence it had been formed. Upon thoſe occaſions, they have concluded, that the water was equal in weight to the inflammable and vital air employed; conſequently, it would thus appear, that the principle of fire, *i. e. their* calorique, or *our* phlogiſtic matter, had not had a ſenſible effect in the gravitation of thoſe bodies.

But, notwithſtanding the accuracy and ingenuity with which thoſe philoſophers proceeded in making their experiments, we are left in this uncertainty, that the effect of the ſolar ſubſtance upon the weight may actually take place, but that it may be too ſmall a thing or quantity for obſervation. To put this ſubject out of doubt, we ought to have ſome ſort of meaſure of that effect which is looked for, in order to judge how far, in thoſe caſes, there were reaſon to expect a ſenſible quantity in the ſubject of experiment. This then is one of the objects which I have here in view, and which I hope may be ſtated in a clear light.

The other object reſpects the antiphlogiſtic theory of *calorique;* for, here I ſhall find an argument, as upon all other occaſions, againſt the theory which holds for principle, That fire proceeds from heat, in other words, that the operation of burning is nothing but the tranſlation of the latent heat of bodies, or its transformation into ſenſible heat ſufficient to enable the body to emit light.

I ſhall alſo procure a confirmation, of

that theory of fire which has now been given, from a ſubject which has not been yet applied to it. What is ſtill perhaps more intereſting to philoſophy, we ſhall have a confirmation of that theory of *inertia* which has been given in another place.

By late experiments, it would appear that water, in its fluid ſtate, does not weigh ſo much as when it has loſt its latent heat, and thus become concreted in the ſtate of ice.

This experiment was moſt ſcientifically contrived by Bergman; and it was executed by Dr Fordyce in a very accurate manner; for now, Sir Benjamin Thomſon, in repeating this experiment, under circumſtances which exclude every ſuſpicion of inaccuracy, has found the ſame quantity of increaſe in the weight of the water upon freezing. This quantity, it is true, is but a little part of the weight of the water; it is not, however, for that reaſon, the leſs neceſſary, in natural philoſophy, to have it properly explained, that is, to have this event generaliſed by being aſſimilated with other events, or thoſe which form the ſyſtem of material things.

If it be ſo, as would appear from thoſe accurate ſcientiſic experiments, that there is in bodies a principle of levity as well as of weight, here is one of the moſt important truths in natural philoſophy. In the received philoſophy of gravitation, we were led to believe, that all matter muſt have weight: Now, ſo far as this were to be held as the true philoſophy of gravitation, here is an experiment which muſt neceſſarily refute the only general principle, which is as yet acknowledged by philoſophers, with regard to the phyſical ſyſtem of bodies.

I have endeavoured to ſhow, in the diſſertation upon the ſubject of gravitation, that our philoſophy, with regard to that ſubject, had been unneceſſarily founded upon a wrong principle; and I have attempted to eſtabliſh the general principle of gravitation upon its true grounds. I there contend, that, although gravitation be general to all examinable or conſiſtent and reſiſting bodies, it does not follow, that all matter, of which bodies are compoſed, ſhould be actuated with the power of union or attraction. We have now been examining matter of another kind in the compoſition of bodies,—matter which has the power, in heat, of ſeparating the gravitating ſubſtance of bodies,—and matter which, in light, may be ſo radiated in ſpace as to ſeparate for ever. It is this ſpecies of matter which ſeems to have the power of giving levity to bodies, inſtead of adding to their weight.

But now we have been inveſtigating a certain phlogiſtic combination of this ſpecies of matter in bodies, or, we have here ſeen the ſeparation of it from the bodies in which it had been contained, as fixed light, united with the other chymical elements.

ments. Are we then to conclude, that this matter had been a cauſe of levity in thoſe phlogiſtic bodies, while in its combined ſtate; and that the gravitating matter had increaſed the weight of the body, upon the decompoſition or ſeparation of that quantity of the ſolar ſubſtance?—Before we form ſuch a concluſion, there are ſeveral things to be conſidered.

Nothing is more certain than that the ſolar ſubſtance oppoſes, reſiſts, and overcomes the action of the gravitating matter which is proper to this globe. But, there are different modifications of this ſolar ſubſtance; and, each of theſe has its peculiar effect. Even in the general modification of heat, the ſolar ſubſtance may either act in oppoſing, balancing, and overcoming the gravitation of the particles of a body, or it may overcome and ſuſpend their concretion; for, theſe are two very different uniting powers *. Thus we have the diſtinction

---

* See Diſſertations, upon Subjects of Natural Philoſophy.

tinction of one ſpecies of heat, when it is the cauſe of fluidity; and of another ſpecies, when it expands bodies, or produces fluid elaſticity.

It does not therefore neceſſarily follow, that, becauſe the ſolar ſubſtance in a body reſiſts the gravitation or ſuſpends part of the weight upon a particular occaſion, or in one modification, it ſhould always do ſo, or upon every occaſion; for, it is only when the ſame modification of the ſolar ſubſtance acts upon a ſimilar occaſion, that we are to ſuppoſe the ſame effect to follow. But, this reaſoning is only general or analogical; and now we want to have particular information or more direct proof.

The principle of levity, in bodies, is founded upon experiment; and, it is both the latent heat of fluidity, and the ſenſible heat of diſtenſion, that appear to be the cauſe of that event, in which the weight of a body is diminiſhed.

It is the latent heat of water which has been the principal ſubject of this experiment. But even the ſenſible heat has appeared to affect the gravitation, and that in a conſiderable degree. This, however, is an experiment of great delicacy and leſs preciſion, as it is much more complicated than the other caſe, *i. e.* of meaſuring the effect of the latent heat when cauſing fluidity; for, in this laſt caſe, the body is weighed in the ſame temperature, when on the one hand it is hard, and when on the other it is fluid. So difficult a matter it is to meaſure this effect of the ſenſible heat, that, had it not been for the ſatisfactory experiment of the ice and water, we could hardly have truſted to the information of the balance with regard to the effect of ſenſible heat diminiſhing the weight.

But, the circumſtances, which renders it ſo difficult to meaſure the effect of ſenſible heat upon the gravitation of bodies with accuracy, do not attend thoſe experiments which ſhould have for object to examine the effects of plogiſtic matter upon the weight of bodies. For, as phlogiſtic bodies may be weighed, both before and after burning, in the ſame degree of heat, there is no other difficulty, in making the experiment, except the including a ſufficient quantity of the inflammable materials in cloſs veſſels, which are then to be weighed, before and after burning, in the ſame temperature. In that caſe, knowing the quantity of heat which had been the conſequence of burning, and which muſt repreſent the correſponding quantity of light which had been ſeparated from the burning bodies, we might then form ſome judgment, with regard to the effect of the phlogiſtic matter upon the actual weight of the body, in which that ſolar ſubſtance had been combined.

Such experiments have been made; and, from theſe it would appear, that the phlogiſtic matter in a body has not any ſenſible effect upon the weight. Therefore, we are to conclude, That it is only heat by which the gravitating power of bodies may be affected; and, that there may be contained in bodies much of the ſolar ſubſtance, in another modification, without the actual weight of the body being thereby impaired.

It will thus appear that the principle, upon which heat acts in a body, is uniformly to oppoſe, reſiſt, and overcome the uniting powers; but, that with which we are now particularly concerned, is the weight of the body, which is thus diminiſhed by heat. We are therefore to compare this effect of heat with that of fixed light in the compoſition of phlogiſtic bodies. In the one caſe, the gravitation of the body is affected, and not in the other; but, in both caſes, it is the ſame kind of matter, or the ſolar ſubſtance, which we are conſidering as combined with the gravitating matter of the body.

We have thus ſtated two facts in which there is no inconſiſtency or contradiction; for, the phlogiſtic ſubſtance in a body, and the modification of heat, although matter of the ſame kind, as being modifications of the ſolar ſubſtance, and commutable elements of bodies, are very different things, or, as powers, act according to very different rules, while in thoſe modifications. But, though thoſe two facts are not neceſſarily oppoſed as contradictory, or inconſiſtent, yet, ſeeing the one leads us to conclude, that the ſolar ſubſtance in a body affects the gravitation, while the other, on the contrary, leads us to believe, that the ſolar ſubſtance may be in a body without affecting the gravitation, it muſt be neceſſary to examine well how far there may be equal evidence in both.

In this caſe, we are to conſider, that the one of thoſe concluſions is a poſitive propoſition, or the one of thoſe matters of fact is a poſitive thing, as founded upon actual obſervation and change *, in which we cannot be deceived, or in which there is abſolute certainty, ſo far as the experiment is fair and truly obſerved. The other, again, is only a negative propoſition, implying that we have not obſerved any effect of the ſolar ſubſtance upon the weight, when that phlogiſtic matter is in the compoſition of the body, or no change in the gravitation when the matter of light is removed from that compoſition. Therefore, all that we can conclude with certainty is this, that the effect, if there be any, muſt be leſs than the quantity which we are juſt able to obſerve.

But though this negative obſervation may not be ſatisfactory of itſelf, yet, when compared in all its circumſtances with the other fact, we ſhall find a degree of evidence for the poſitive propoſition or phyſical truth which we had formed from that negative,

---

* See an Inveſtigation of the Principle of Knowledge, part 2d. ſect. 3d.

negative, viz. That the gravitation of the body is unaffected by the phlogiſtic ſubſtance in its compoſition. But, in order to ſee that evidence, we muſt now compare thoſe two experiments in all their circumſtances; and, in thus examining the particulars, we may judge how far we ſhould have perfect confidence in the experiments, by which thoſe facts or phyſical truths muſt be eſtabliſhed.

We have here two caſes to compare, viz. the experiment in which the obſervation is a poſitive thing, and that in which it is only negative. Now if, in the poſitive caſe, the quantity of the heat employed were a conſiderable thing, while, in the other, the quantity of the ſolar ſubſtance were but ſmall, we would not heſitate to conclude, that, notwithſtanding of there being no effect obſerved, this might actually take place, but be too ſmall a thing for our obſervation. But, it is the very oppoſite, in the caſes we are now conſidering; and this muſt lead us to form a very different concluſion.

In the experiment where heat appears to have an effect upon the weight, the quantity of that heat is but ſmall, it being only the latent heat, or that which is neceſſary to render the body of ice fluid; the poſitive information however of the experiment leaves no room to doubt with regard to the concluſion, provided there be no fallacy in the obſervation of ſo ſmall a quantity; and, this quantity in the reſult being ſmall, is no defect in the evidence, as it correſponds ſufficiently with the cauſe, to give the experiment all the appearance of truth.

In the experiment, again, of burning inflammable vapour and vital air, the quantity of light, (valued in heat) which is ſeparated in burning, bears ſo great a proportion to the gravitating body, compared with the latent heat of the water in the other

ther caſe, that, were it to affect the weight in a ſimilar manner, this could not fail to be perceptible in the experiment, provided that both experiments were executed with equal accuracy and ingenuity.

With regard to this accuracy in contriving and executing the experiments, there ſeems to be no reaſon to diſtruſt either one or other; therefore, we are to conſider them both as equally correct.

Upon the whole, then, the ſtate of the caſe is this. In the one experiment, the method is ſo perfect, the accuracy of obſervation ſo ſufficient, and the reſult (ſo far as has yet been tried) ſo uniform, that, though the quantity of the effect be but ſmall, we cannot reaſonably doubt the truth of the obſervation. In the other experiment, again, the quantity of the matter, or cauſe, which ſhould have the effect, is ſo conſiderable, that a ſmall effect, if there had been any, ſhould be a perceptible ſubject of obſervation. Therefore, we muſt admit this general concluſion, That, whilſt heat has a ſenſible effect upon the weight of bodies, the ſolar ſubſtance, or matter of light, which is in the modification of phlogiſton, would appear to have no ſuch effect.

It was no ways neceſſary to my theory of the ſolar ſubſtance, and its various modifications, that this ſhould have been the actual ſtate of things; but now, that ſuch would appear to be the fact, I may be allowed to employ it as a principle in our philoſophy. Therefore, let us now compare the two theories of fire with this phyſical truth ſo far inveſtigated.

In the theory of *calorique*, the principle of fire is evidently meant (however inaccurately or unſcientifically) to be placed in the latent heat of bodies, or in that of fluid elaſticity; but, the latent heat of fluidity, as well as the ſenſible heat of dilatation, has been found to affect the weight of bodies. Conſequently, were the principle of fire to be conſidered as any ſpecies of heat which had been latent in bodies, there would be reaſon to look for a great effect of this matter upon their weight. Here then that theory is plainly inconſiſtent with matter of fact, with which it ſhould have agreed.

This, however, is not the caſe with the other theory. This theory maintains, that the principle of fire is a certain quantity of fixed light in bodies, which is conſidered as phlogiſton; and, the action or effect of this matter, or modification of the ſolar ſubſtance in bodies, is ſo very different from that of heat, that it is not unreaſonable to ſuppoſe, that the one may have an effect upon the weight of bodies, and that the other may have none.

SECTION II.

The Solar Subſtance Examined, with regard to Inertia.

HAVING inveſtigated, ſo far as we can, the principle of levity in bodies, we are thus led to a curious ſubject of diſcuſſion, a ſubject intimately connected with gravitation, and a ſubject with which natural philoſophy is not a little concerned.

Our object in this diſſertation being to examine the ſolar ſubſtance in the ſeveral modifications of light, heat, and phlogiſton or fire, we may here inquire how far the matter of thoſe modifications ſhall appear to have *inertia*, or not. Till of late, ſuch an inquiry might have been but an idle ſpeculation, or a fruitleſs undertaking; it is ſo far otherwiſe at preſent, as we have now acquired ſome data by which to reaſon upon the ſubject.

It has been a received notion in natural philoſophy, that all *matter* neceſſarily muſt have *inertia*. That all natural bodies, which we are able to examine, have *inertia*, as they have weight, is a matter of fact, and not a truth flowing from any univerſal propoſition with regard to *matter* ; it is moreover evidently neceſſary, in the ſyſtem of this world, that thoſe bodies ſhould be ſo conſtituted ; but, it does not follow from this, that all *matter*, or any thing elſe beſides thoſe in which it is neceſſary, ſhould have this property which we find in gravitating bodies, as I have endeavoured to illuſtrate in another place [*]. But now we have an opportunity of conſulting nature in relation to this ſubject, which can only be decided by experience ; and, in finding any *matter* without *inertia*, we ſhall acquire a phyſical truth, and an important principle in natural philoſophy.

Now,

---

[*] Diſſ. upon Subjects of Nat. Phil. Part III. Diſſ. I.

Now, ſo far as we have been reaſoning upon a fact, viz. that heat affects the weight of bodies; and, ſo far as phlogiſtic matter in bodies has not weight, there is a proper ſubject for experiment, in order to know if that phlogiſtic matter, which has no weight, be poſſeſſed of *inertia*, or not. For, by employing ſuch bodies as a pendulum in meaſuring time, we ſhould find how far thoſe bodies have more *inertia*, (according to the received notion with regard to that power), in proportion to their gravitating matter, than other bodies which are not phlogiſtic.

This experiment has, I believe, been made with ſufficient accuracy to decide the queſtion. For, although it is but a negative propoſition that is founded upon the experiment, affirming that *no* difference had been obſerved; yet, ſeeing that the quantity of the thing to be obſerved is a ſufficient object for giving information, the not appearance of it is an abſolute proof, or poſitive evidence, that it is wanting, in that caſe. Therefore, the cardinal fact upon which this important truth depends, is the actual exiſtence of that ſolar ſubſtance, without weight, which we have termed *fixed light*, in the compoſition of phlogiſtic bodies. Now, it has been the object of this diſſertation, upon the ſubject of fire, to aſcertain that fact ; and, at preſent, philoſophers muſt judge how far that end has been attained.

We have thus acquired data by which to reaſon concerning the ſubject of *inertia*, and to form the moſt aſſured judgment in relation to that which has been conſidered as an univerſal principle of material things.

Inertia is properly a quality of natural bodies, in like manner as is weight. It is not a moving nor a reſiſting power, properly ſpeaking, but a capacity of perſevering in a ſtate, whether of motion or of reſt, but without having an active power to reſiſt a change. Without making this neceſſary diſtinction of power and capacity, (as has been done in the before quoted diſſertation), it is impoſſible to underſtand the nature of *inertia*.

Inertia is the law of action and paſſion by which motion is tranſlated from one body to another, as well as continued in the body which has been made to change its place; and, in this tranſaction, the rule obſerved is the actual weight of the bodies. Therefore, according to this theory, matter that did not gravitate could not affect the *inertia* of a heavy body with which it ſhould be united. Now this, we have ſeen, is confirmed by actual fact, or a proper experiment.

But we have been alſo conſidering a certain ſpecies of matter, which not only does not gravitate, but which diminiſhes the actual weight of a heavy body; now, Does this matter alſo affect the *inertia* of that body, dy, as it ought according to the above theory? This is a queſtion which is not as yet decided by experience. Dr Fordyce has propoſed an experiment of this kind, upon the ſuppoſition, I preſume, that the latent heat of water impairs its weight, but not its *vis inertiae.* According to our theory, the *inertia* muſt be always in proportion to the actual weight. Dr Fordyce's propoſed experiment, if practicable, would decide this point. In the mean time, let us reaſon upon the ſubject of *inertia*, ſo far as we have acquired principles for that end.

We have found, that there is matter which not only does not gravitate, but which ſuſpends part of the gravitating power of bodies. Now, I aſk, What ſhould be the nature of this matter in relation to *inertia?* It cannot give *inertia* upon the principle of gravitating bodies; for, inſtead of gravitation, it has the oppoſite power. What then is the oppoſite to *inertia*, *i. e.* that paſſive power or capacity of receiving an imparted motion according to a certain rule? Is not this *activity* and exertion, a power continually acting, and tending to ſome end? This then is the proper attribute of that matter which diminiſhes the gravitation of a body. But, this is alſo the attribute of gravitating matter; for, gravitating matter is that which in bodies is continually acting and exerting power directed to an end.

We thus find two different kinds of matter in bodies, neither of which have the quality of *inertia;* they are conſtantly acting with oppoſite intentions, and then form the proper conſtitution of natural bodies, which acquire *inertia* in the balance of thoſe oppoſite powers, at leaſt, it is there, and there alone, that we find *inertia.*

To ſee how little reaſon we have to look for *inertia* in any other thing, let us ſuppoſe a certain ſpecies of matter, which did not gravitate, to have *inertia;* What would be the nature of this thing? If, according to the common notion of matter, this be a thing which is extended, then it is a body with magnitude and figure; and now we may conſider it in relation to gravitating bodies which have *inertia* and *momentum*.

Let the body which does not gravitate be impelled by the body moving with *momentum;* I aſk, In what manner, or according to what rule, is the velocity of the moving body to be divided between the two bodies? According to the rule of our experience, the gravitating body ſhould move the oppoſing body, without loſing any of its own velocity; for, it is only in proportion to the weight of a body at reſt, that it can diminiſh the velocity of the moving body in receiving motion. In that caſe, the two bodies would move together with the firſt velocity; and this would be the creation of motion without a cauſe, or the action of one body upon another without any reaction, which is inconſiſtent with the actual courſe of nature.

Let us again ſuppoſe the gravitating body, at reſt, impelled by the body which moves with *inertia*, but without *momentum*. In that caſe, the two bodies muſt either move together, or both reſt. If the bodies move, here is motion created, and *momentum*, from nothing; for, the firſt moving body has no *momentum*, and now the heavy body moves with *momentum*. If again the two bodies do not move, but remain at reſt in conjunction, here is motion annihilated, or action ended without reaction or effect. Thus we are led into concluſions which cannot be admitted.

We have thus conſidered the matter with *inertia* as being a thing extended; let us now ſuppoſe it to be without extenſion.—Matter without extenſion muſt exiſt in acting or in ſuffering, that is, either in action or in paſſion. If in the firſt, this action muſt be that of a moving and reſiſting power, ſuch as, for example, that of gravitation; but this is not *inertia*, which is only ly a capacity of being moved ; it is the very oppoſite of *inertia ;* ſo that a thing cannot have thoſe two attributes at the ſame time. If again that unextended matter ſhall be ſuppoſed to exiſt in paſſion or capacity, this muſt be either the capacity of receiving motion, or of being made to feel. Now, it muſt be the firſt ; for, a material thing cannot be ſuppoſed to feel, which is the property of mind ; and it is with this that matter is contraſted. But, to what purpoſe have the capacity of receiving motion ? It has now been ſhown, that this thing, moving only with *inertia*, could not move any of the bodies of the material univerſe, without creating *force* which it has not, as having no weight.

Therefore, no kind of matter, or no other thing beſides gravitating bodies with moving and reſiſting powers, can be ſuppoſed as having what is called *inertia*, which is properly a certain law with regard to the communicating velocity or motion.

If it ſhall be allowed us thus to conclude, That the ſolar ſubſtance cannot be poſſeſſed of *inertia*, but that it may act variouſly in relation to the matter which is proper to gravitating bodies, then here is an argument againſt the commonly received notions of natural philoſophy, in which the *inertia* of matter is aſſumed as an univerſal principle, or in which it is ſuppoſed to be a reſiſting power, inſtead of that which it is, viz. a mere capacity.

We may now form a theory with regard to light, the principle of fire in bodies; for, we have found that it is a ſubſtance which has no weight, and which, in this ſtate of fixed light, or phlogiſton, does not affect the gravitation of the body to the earth, as it may do in another modification; that is to ſay, being converted into heat, it then becomes in ſome meaſure a principle of levity, in the heated or the fluid body.

Neither light nor heat act, like phyſical bodies, by their weight, their figure, or their volume; therefore, light and heat are not to be conſidered as phyſical bodies, but as certain *powers* affecting phyſical bodies with regard to which they act. We indeed ſpeak of a body of light; but this means only light coming from a body. If bodies are viſible, then light properly is not viſible; light is the means by which we ſee colour, and thus are made to perceive bodies, to which we attribute colour as well as magnitude and figure. Heat again is never ſuppoſed to be a body; we only ſpeak of heat as a quality in bodies, and as a feeling of our ſenſe.

Light not being a body, although conceived as moving with extreme velocity, the effect of that ſolar ſubſtance in phyſical bodies is not progreſſive motion; the effect of light and heat in bodies is the cauſe of *ſenſe*, of *dilatation*, and of *fluidity*. But, *inertia* is inapplicable to theſe effects of light and heat. We are now to examine how far there are flowing from light any other effects, by which we might be led to attribute *inertia*, the property of heavy bodies, to this ſolar ſubſtance which we have been conſidering as light and heat.

If light ſhall be conſidered as moving by its proper energy, in like manner as a heavy body falls, then it is properly a moving power, and cannot be ſuppoſed to be acting with *inertia*, like a projected body. It may indeed be alledged, that we never can in this manner prove any thing with regard to the *inertia* of light, as we have not perhaps the means of knowing how far light moves with its proper energy, or if it be moved by any other thing; but we may convert the argument, and reaſon thus: If light has not *inertia*, then, in moving, it muſt act by its proper energy, and, conſequently, be a moving power, as we conceive to be the caſe with gravitation—a power of that kind which cauſes motion where motion did not exiſt, and not a paſſive power or capacity of communicating the motion or velocity which it had acquired.

If it ſhall be allowed, that we have now proved, from fact or experience, that the matter of light, when confined in bodies, has not *inertia*, or the capacity of receiving and communicating velocity, it muſt be concluded, that, when light moves from one body to another, or through ſpace, it is actuated by its own proper energy, and therefore is not to be conſidered as a thing projected or moving with *inertia*. Here again there is an opportunity of having recourſe to experience, or examining nature with regard to the fact, how far there is reaſon to ſuppoſe it to be true that light moves without *inertia*. For, having it in our power to examine the effect of moving light impinging upon bodies, as well as the circumſtances of bodies emitting light which had been in a ſtate of reſt, we may judge how far the phenomena of nature are conform, on the one hand, to that theory in which light is ſuppoſed to have no *inertia*, or, on the other, to that in which *inertia* is ſuppoſed to belong to every kind of matter.

Let us now ſtate the caſe. As the weight of the body, in which fixed light or the principle of fire reſides, is not affected by that phlogiſtic matter which is in its compoſition, ſo neither is the *inertia* of the body affected by this ſolar ſubſtance which is in a fixed ſtate. But being diſengaged, by the decompoſition of the body, from that fixed ſtate, this principle of fire moves, in the quality of light, with the moſt amazing velocity. Here a queſtion naturally occurs, How far this moving matter ſhould be poſſeſſed of *inertia*, as communicating that motion to bodies which it meets, bodies which have the capacity of reſiſting and arreſting that moving ſubſtance. Here then is an opportunity given for trying the theory which has now been formed with regard to the principle of fire.

The ſubſtance of light being found to have no weight, neither ſhould it have *inertia* and *momentum;* conſequently, it ſhould be incapable of tranſlating or imparting its progreſſive motion to bodies which it meets. But, if we ſhall find the ſolar rays to have any effect in protruding bodies upon which they impinge, here would be a manifeſt confutation of our theory. If, on the contrary, the moſt moveable thing conceivable be not affected in that manner, by this amazingly ſwift moving ſubſtance, the new theory will have received every reaſonable confirmation. Here then we are to refer to experience.

We have, in the light duſt of a chamber ſuſpended in the air, and infinitely more in the minute particles of ſmoke, bodies the moſt minute and the moſt moveable that can be imagined. Now if theſe bodies, expoſed to the impulſion of the ſun's rays, be not in any ſenſible degree moved in that direction, but preſerve their place or move in their own directions, notwithſtanding the conſtant influx of the luminous fluid moving with extreme velocity, we muſt conclude, that thoſe bodies are not otherwiſe affected, except in being heated by the light which they extinguiſh or retain. But, ſo far as we can perceive, the rays of light, impinging on thoſe moveable bodies, have not the ſmalleſt effect in giving them progreſſive motion.

It muſt not be here alledged, That, however minute thoſe bodies are, we may conceive the quantity of gravitating matter in them to be ſo great, in proportion to the rays of light, as to render the effect of impulſion a thing altogether imperceptible. This would be a mere ſuppoſition, not only deſtitute of any ſhadow of reaſon, but plainly in oppoſition to every thing that we may gather from appearances.

In the firſt place, if the effect of impulſion, where the velocity is ſo immenſe, be ſo imperceptible, How comes it, that the heat, excited by the extinction of a ſmall portion of that light, exerts a diſtending force that ſeems to be irreſiſtible?

Secondly, if the ſolid matter in thoſe bodies bears ſo great a proportion in relation to the matter of light, How comes it, that the moſt hard and denſe tranſparent body tranſmits the light equally in every poſſible direction, while the moſt rare fuliginous ſubſtance arreſts that light in every direction *?

Laſtly, though the quantity of light impelling one of thoſe minute bodies, during the ſpace of one moment, were ſo ſmall a thing as not to have a perceptible effect, yet, in continuing for a ſpace of time, that ſeries of impulſions ſhould certainly protrude the body which, according to all appearances, ought to be extremely affected even by one.

---

* See Diſſertations on Subjects of Natural Philoſophy.

Therefore, in ſound philoſophy, where no abſolute truth can be founded upon mere ſuppoſition, and where, in phyſical ſcience, our imagination goes for nothing without the teſtimony of external information, we muſt conclude, That light, moving with its immenſe velocity, whether tranſmitted, reflected, or arreſted by bodies, imparts no progreſſive motion to them, conſequently, has no *inertia*, as we were led to ſuppoſe from our theory.

Let us now recapitulate what we have found with regard to this intricate ſubject, in order to draw a general concluſion.

Firſt, it has been proved that there are certain phlogiſtic bodies in which there is contained a great quantity of the ſolar ſubſtance, in a ſtate which I have termed *fixed light*. Secondly, that this ſubſtance neither has gravitation, nor does it affect the weight of bodies, when in this particular modification. Thirdly, that this ſolar matter has no *inertia*, when moved with the heavy body. And now, laſtly, that when this ſolar ſubſtance, in moving with the velocity of light, impinges on a body, it then has no *momentum* or *inertia*, by communicating any of its velocity to the body; but, it is either reflected from the ſurface of the body, is tranſmitted through it, or arreſted in its ſubſtance, and thus affects the body in a ſenſible manner, but without giving any progreſſive motion. Here then the propoſition, which I had maintained in my Diſſertations upon the Powers of Matter and Qualities of Bodies, in which I affirmed, That *inertia* belongs to gravitating bodies alone, and is always in proportion to their weight, is properly confirmed by experiment.

We have alſo in this an explanation of a certain natural appearance, which is abſolutely inconſiſtent with the commonly received philoſophy of matter. For, light emerging from a burning body moves with all that velocity, ſo far as we can perceive, with which it arrives to us from the ſun; but, ſuppoſing the matter of light inert, How comes it to acquire that amazing power of being moved with ſo great velocity? It cannot be moved by its own energy, becauſe it is inert; and it cannot be moved, in that direction, by the action or impulſion of the gravitating matter with which it had been combined in the body; therefore, we muſt ſeek for a moving power, by which this ſuppoſed inert matter may be actuated. But, to ſeek a cauſe for the motion or propagation of light through bodies or through ſpace, is the ſame as to ſeek a cauſe for gravitation; theſe are effects of nothing that we know, and, conſequently, can only be aſcribed to the Firſt Cauſe; they are abſolute phyſical principles, or facts which, we have reaſon to believe, cannot be traced any higher in the ſeries of natural events.

In the philoſophy again which we have

now ſupported, no ſuch difficulty occurs. According to that philoſophy, light is a ſubſtance moving according to certain laws, and for a certain purpoſe; therefore, when not affected or conſtrained by any other power, this ſubſtance, like that of gravitating matter, moves according to its nature, that is, in obſerving thoſe rules by which its action is meaſured and directed. Here the appearance of light moving from burning bodies is explained, or conceived in conſiſtency with every other part of that philoſophy. But if we ſhall found any of our philoſophie reaſoning upon this principle, that *inertia* is a univerſal property of matter, and not ſolely of gravitating bodies, then this appearance, of light proceeding from burning bodies, is a fact altogether inconceivable, or irreconcilable with other facts in which we are all agreed.

Mathematicians alledge, that the refraction of light proceeds upon the principle of gravitation; and that the matter of light muſt therefore be conſidered as a thing poſſeſſed of *inertia.* Let us now conſider that propoſition.

Perhaps *inertia* is one of the qualities of bodies moſt difficult to underſtand, as it is commonly confounded with what are properly moving and reſiſting powers, which *inertia* is not.

That bodies, which are moved by any power, continue to move in that direction and with that velocity which they had received, is a matter of fact, which is not theory; but when we come to make a theory of that fact, by generaliſing this action or this paſſion, it is then that we may either form a true or an erroneous theory. If we acknowledge *inertia* as univerſal to bodies which are heavy and reſiſt compreſſion, we ſhall form a true theory, or one which will be conſiſtent with every other fact; but if we impute *inertia* to any other thing, to the matter of light for example,

ample, without having ſome direct or poſitive evidence for that fact, we ſhould then generaliſe improperly, and form a theory that might be found erroneous.

According to the inveſtigation which I have made with regard to that ſubject, *inertia* is the law obſerved by nature, in the communication of velocity among moving bodies; it is neither a moving nor reſiſting power, properly ſpeaking; it is a paſſive power or capacity, in bodies, of mutually imparting or communicating their velocities.—Now this is a diſtinction that is abſolutely neceſſary to be made, in a ſcience that treats of moving and reſiſting powers; and, natural philoſophy is much concerned to have no doubts left upon this ſubject; for, if *inertia* is to be attributed to the matter of light, notwithſtanding of the evidence here given to the contrary, What truſt could be put in the ſcience of phyſics, where ſuch inconſiſtencies had occurred?

I have endeavoured to ſhow (in Diſſertations upon Subjects of Natural Philoſophy) that the refraction of light does not depend upon gravitation or the attracting powers of bodies, but that it is cauſed by a power of another kind which is ſituated at the ſurfaces of bodies. I ſhall now ſtate the caſe according to my view of the ſubject; and let thoſe who are of another opinion either do the ſame with regard to their view, or ſhow wherein I have taken an erroneous ſtep in my reaſoning.

Refraction is an affection of light, when either entering into the ſurface of a denſe body, or emerging from it; therefore, in order to acquire ſome knowledge with regard to the cauſe of that affection, it muſt be proper to conſider other affections of the ſame kind which take place at the ſurface of thoſe bodies.

A ray of light, falling upon the ſurface of a body, either penetrates it, or, it is reflected from it; in this laſt caſe it loſes its former direction, and acquires a new one. But as this new direction may be oppoſite to the one in which it had moved before, this ray of light muſt be by us conceived as here reſiſted, as having its firſt motion deſtroyed, and as having a new motion given it in the oppoſite direction. Now it is impoſſible that the gravitation of the body can act in this manner, ſo as to produce that effect of moving from the body to which it had been directed; therefore we muſt ſeek for the cauſe of this appearance in ſome other power.

As the gravitation of the body is not the cauſe of reflexion for the incident light, neither is the hardneſs of the body, nor any other quality; for, the light is reflected without coming in contact with the ſurface of the body. Therefore, there muſt be a reſiſting and impelling power placed at this ſurface, by which the light is reflected in the oppoſite direction to that in which it had arrived. This is the conception which we naturally make according to our notions of projected inert bodies.

But, it is only part of the light which is thus reflected; the reſt paſſes through the reflecting atmoſphere of the tranſparent body, and, entering the ſurface of the body, is tranſmitted through its ſubſtance as if it were a vacuum. We have therefore reaſon to conclude, that a ray of light, in paſſing through this reſiſting atmoſphere which acts with perfect elaſticity, is firſt retarded in its velocity, and then accelerated as it leaves the impelling atmoſphere in entering the body *.

---

* It is not here propoſed the giving a deſcription of an operation of which we only know the effect, and have not any principle perhaps by which to judge the mode of action, as we do with regard to elaſtic bodies which impel each other; and this expreſſion of an atmoſphere is only meant to illuſtrate this propoſition that it is not neceſſarily by gravitation that refraction

If that be the caſe, (as it is perhaps otherwiſe inconceivable,) then, it is only when the ray of light paſſes through that atmoſphere perpendicularly that it may be equally impelled ſo as to preſerve the direction of its incidence. When it penetrates in an oblique direction, it muſt be unequally impelled, in leaving the elaſtic atmoſphere; and it may thus be made to take a direction more inclined to the perpendicular at that place, provided that atmoſphere be not perfectly uniform, but act with greater intenſity in that ſide which is in contact with the body, than in the other by which the light was firſt reſiſted.

Here then is a cauſe for change of direction, when this ray enters the ſurface of the body; and, if there is no other cauſe that may be aſſigned for this actual effect, we muſt conclude, that ſuch is the nature of

---

is performed, but more probably by a power acting upon the oppoſite principle,—a power ſituated at the ſurfaces of bodies, or where parts of different denſities take place.

of this atmoſphere by which we are certain that light is reflected in approaching to the ſurface of bodies.

I have ſhown (in the before mentioned diſſertations) that this reflecting and refracting power, or atmoſphere ſituated at the ſurfaces of bodies, is not compoſed of the gravitating matter of this globe, but that it is a modification of the ſolar ſubſtance. I have there alſo given the reaſons for believing that the progreſſive motion of light is not affected by the gravitating matter of bodies. But now another argument may be formed againſt the ſuppoſition of refraction being the effect of a gravitating power. The rays of light are variouſly affected in refraction, that is to ſay, the ſeveral ſpecies are affected in different degrees, and different ſubſtances affect them variouſly; therefore, the cauſe of this deflection of light cannot be a power acting uniformly in producing its effect. But, the power of gravitation acts uniformly in producing its effects; for, all bodies, whatever be the nature of their ſubſtance, whatever be their weight, their volume, or their figure, fall equal ſpaces in equal times. How then could we ſuppoſe the different ſpecies of light ſo variouſly affected in refraction, if this deflection were cauſed by the power of gravitation?

Thus, in examining refraction, or the affections of light at the ſurfaces of bodies, we find no reaſon for ſuppoſing *inertia* a property of the ſolar ſubſtance. On the contrary, we can perceive nothing but action and reaction, moving and reſiſting powers, in all the various modifications of that ſubſtance which is propagated from the ſun, in order to actuate the inert bodies of this world. Therefore, we have every reaſonable confirmation of this fact, or phyſical truth, that the principle of fire has not weight; and alſo, that it has not *inertia*, either in its fixed or its moving ſtate, that is to ſay, it is properly a moving and reſiſting power, and not a thing endued with the paſſive capacity of being moved by the imparted velocity of another thing, or of imparting its velocity to bodies on which it ſtrikes.

The general reſult of this phyſical inveſtigation is to ſhow, that there is no reaſon to look for any thing inactive or abſolutely paſſive, except ſpace, which is unalterable, and in which bodies are conceived to move; particularly, that there is nothing abſolutely ſolid, or no ſolid which is abſolutely hard and incompreſſible; and that all material things move, and are moveable, there being no reſt in any thing but in the places of ſpace, which bodies occupy in ſucceſſion.

Here is a doctrine that muſt revolt the opinions of thoſe who found their phyſical ſyſtem upon an inactive, abſolutely hard, and abſolutely incompreſſible ſubſtance, of which natural bodies are to conſiſt;—a ſubſtance, the idea of which is undiſtinguiſhable from that of ſpace, except in this *inconſiſtency*, viz. that it is firſt made abſolutely inactive or inert; and then it is made active, as moving or changing its place in ſpace. Now there is no other way of reconciling that inconſiſtency, except in adopting moving and reſiſting powers, in order to actuate that inert ſubſtance which had been inconſiderately founded upon as a principle. But, in that caſe, they leave nothing in their fundamental idea of matter but the property of ſpace, viz. that of being abſolutely paſſive, extended, and unalterable in the order of its parts. This, no doubt, is an idea which is abſolutely neceſſary in natural philoſophy; but it is an idea which is certainly inapplicable to phyſical bodies. Of this, then, we have the teſtimony of nature, in oppoſition to our imaginations; for, we have, in our experience, the poſitive information of action and change in every thing; and this is a fact, or principle, which we cannot deſert,

ſert, for one moment, without running into abſurdity or contradiction.

If we ſhall thus lay aſide our groundleſs or inconſiderate notions, with regard to the hardneſs and ſolidity of matter and inactivity of material things, we may then take an enlarged view of the material univerſe, a view in which perhaps may be reconciled the inconſiſtent ideas of body and mind, which are ſo often entertained by thoſe who reaſon upon phyſical ſubjects with metaphyſical principles, and upon metaphyſical ſubjects with ideas which are only applicable to phyſical things; it is as follows:

Body in the abſtract, *i. e.* a thing conceived with a certain magnitude and figure, muſt be inert; for, ſo we have conceived it, and it is no otherwiſe than as we conceive; this thing, therefore, cannot change, although we have the power of changing our idea in conceiving various magnitudes and figures. Such a body as this is only a certain portion of ſpace, which we have imagined or conceived in a certain manner, by limiting the magnitude and ſpecifying the figure. But, to this conceived portion of ſpace, let us give any power and energy, and then we have phyſical or material body; a thing which has moving and reſiſting powers, and which has alſo *inertia*, *i. e.* the capacity of giving and receiving motion or velocity according to a certain rule,—viz. the *reſpective weights* of thoſe communicating bodies. This is the idea of *inertia* which I have given in diſſertations upon the powers of matter, &c.; and I have now endeavoured to confirm that theory by direct experiment.

PART VII.

Of the Solar Light compared with that of Fire.

THE light which has been the ſubject of this diſſertation, is properly that which proceeds from fire or flame, and not the light which comes more immediately from the ſun. But now, having formed a certain theory with regard to that light which we have examined, we may inquire how far thoſe qualities of light or that theory may be generaliſed, in being properly applicable to all light.

In the light which comes from fire, there are different ſpecies predominant, firſt, according to the nature of the burning ſubſtance, whether it is either on the one hand combuſtible, or on the other inflammable; and, ſecondly, according as the emitted light is of leſſer or greater intenſity. By this means there occur three different caſes for conſideration, or ſubjects to examine; theſe are, firſt, the light of greateſt intenſity, which is ſuppoſed to be white, as having leaſt particular colour; ſecondly, the light of combuſtible bodies in its leaſt intenſity, which is ſuppoſed to be red, as having that particular ſpecies predominant; and, laſtly, the light from flame, ſo far diminiſhed in its intenſity as to become of a blue colour.

It is only the red ſpecies which has been here compared with the white or more perfect light; I call it perfect as having its juſt proportion of all the different colouring ſpecies which conſtitute that perfect light which we have from the ſun for the purpoſe of perceiving bodies. In this compariſon, we have found the white ſpecies as being moſt perfect or powerful, for the purpoſe of exciting viſion; but we have found the other moſt powerful for exciting heat, proportionally to its lumination. Now theſe are the two material purpoſes for which the ſun illuminates this earth; and theſe are the two purpoſes for which the art of man has contrived to employ fire, in the abſence of the ſun, or in the defect of that great cauſe of light and heat.

We may now conſider this conſtitution of light, the principle of fire, in the view of final cauſes; for, unleſs we can perceive a purpoſe, in the ſyſtem of this world, for that effect of the compoſition, by which the ſeveral colouring ſpecies loſe ſo much of their heating power, and acquire that of illuminating bodies for the purpoſe of viſion, we might be diſpoſed to doubt of the reality of that inveſtigation which has now been made, and to conſider thoſe appearances of light and heat to be ſtill anomalous; eſpecially ſeeing that this ſuppoſed general rule has been concluded from an obſervation which is only partial, in a ſubject where there is ſtill room for much inveſtigation.

With this view, then, we are now to obſerve, that the conſtitution of things, in which the more ſimple ſubſtance of light is the moſt powerful for exciting heat comparatively with its lumination, ſeems to be wiſely contrived for the purpoſe of this world or our animal oeconomy; for, in abſence of the ſun, we thus moſt eaſily procure heat, which is one of the neceſſaries of life. The uſe of light for the purpoſe of viſion, during ſhort intervals of darkneſs, even were it not otherwiſe to be ſupplied, is but a matter of ſecondary conſideration, or a mere convenience; whereas, heat is a neceſſary of life which cannot be diſpenſed with, even during the ſhorteſt interval. Therefore, every means for obtaining a ſecurity for that end, and for procuring the other benefits of heat from the operation of fire, exhibits the marks of wiſe contrivance in a benevolent deſign.

The ſimple ſpecies, or different coloured lights, have not properly for object the moſt neceſſary purpoſe, that of *ſeeing bodies*, or perceiving magnitude and figure in external things, but the more refined or ſubſequent purpoſe, that of *diſtinguiſhing* thoſe bodies which are *perceived* by light and ſhade, or by the compound white light contraſted with blackneſs or darkneſs. Thus the one has the more neceſſary purpoſe of viſion, and the power for that purpoſe in a high degree, or upon a moſt extenſive ſcale, while it has the power of heating proportionally in a leſs degree; whereas, the other has the heating power, as an object in the abſence of the ſun, in a high degree, or upon a more extenſive ſcale, while its power for giving viſion is diminiſhed, or decreaſes at a greater rate, becauſe the particular colour of objects is only a ſecondary conſideration in the ſyſtem of viſion.

In order to ſee this wiſe conſtitution, with regard to the nature of light, we have but to conceive things to be otherwiſe contrived,

trived, and that the compound light had been equally powerful for exciting heat as it is efficacious in procuring viſion; in that caſe, according to the preſent conſtitution of our organs, either the heat, ariſing from the influence of the ſun upon this earth, muſt have been intolerable, or the neceſſary heat deficient. But now, having the white or compound light ſo efficacious for viſion in perceiving bodies, and ſo much diminiſhed in its immediate heating power, we find a wiſe intention for the oeconomy of this world, which requires a great influx of light for the purpoſe of vegetation, as well as for that of rendering bodies viſible by means of light and ſhade.

In the preſent conſtitution of things, we are enabled to ſee with the compound ſolar light, in ſuch a ſmall degree of intenſity, that, if this light had equal heating power in proportion to its intenſity, as that coloured more ſimple ſpecies which we have been examining, we could not have ſuffered the heat of the ſolar light or that of day; and if, on the other hand, the intenſity of that ſolar light had been then adapted to our ſenſe of heat, it would have been diſqualified for affording that great latitude, which the preſent conſtitution admits of in the ſenſe of viſion. But having, by the diminiſhed heat of the ſolar light, the capacity of employing it for viſion, from its greateſt intenſity when it is immediately from the ſun, to that extremely diminiſhed intenſity from the reflexion of Jupiter or Venus, and having the heat, which comes from the light of fire, ſo much increaſed for the purpoſes of life, we muſt in this ſee the beauty of deſign, in which the means are wiſely choſen and the end benevolently intended.

I have been repreſenting the heating power, of the white or compound light, to be increaſed as that perfect light is ſeparated into its conſtituent parts, or, that the heating power of the more ſimple ſpecies is diminiſhed by their compoſition into perfect light. But we may convert the propoſition, and maintain, That the luminating power of the ſimple ſpecies, which are calculated for giving the ſenſe of colour, is increaſed by their compoſition into perfect light; for, it is only comparatively, with their power of giving viſion in perceiving bodies, that their capacity for exciting heat has been eſtimated. It muſt be evident, that theſe two caſes of ſuppoſition will give the ſame appearances in our experiments, conſequently, that this event may be expreſſed either in the one way or the other.

Thus, the ſimple ſpecies in light, (which enable us to diſtinguiſh objects by giving colour to the ſenſe,) may be conſidered as increaſing their luminating power at a greater rate in being united; whereas, they loſe their luminating power more than their heating quality, in being ſeparated. But as, in burning bodies, there is found the means for ſeparating thoſe ſpecies, we thus find a certain proviſion for heat, among bodies upon this earth, in abſence of the ſun, as well as white flame for ſupplying light. It is in this manner that there is procured much heating light, ſo uſeful in the ſyſtem of this world,—light which is radiating from bodies, without giving any viſion for perceiving objects. This then is that *inviſible light* which we have been inveſtigating,—a term which does not neceſſarily imply a contradiction.

Animal heat being a ſubject of ſuch importance in the ſyſtem of this world; and, fixed light, or phlogiſtic ſubſtance, being conſidered as the ſource of that heat, we may now examine how far this conſtitution, of *inviſible light*, ſhall be found connected with that operation in which animals procure their vital heat.

The decompoſition or reſolution of phlogiſtic ſubſtances, by means of the oxigenating proceſs of vital air, is now well underſtood;

derſtood ; but, according to the theory of fire, which has been here inveſtigated, that proceſs of reſolution muſt be as neceſſarily attended with the extrication of fixed light, as it is properly the forming cauſe of either carbonic acid, on the one hand, or of an aqueous ſubſtance, on the other, according as it is either the combuſtible or the inflammable materials, which are conſumed on that occaſion.

Thus, in the production of carbonic acid or fixed air, we procure the means of inveſtigating that operation of decompoſing phlogiſtic ſubſtance,—an operation which, we have reaſon to believe, is performed in the lungs of animals,—and an operation in which there muſt be acknowledged the extrication of *fixed light*, which is the cauſe of heat in fire.

According to the theory of fire and phlogiſton, upon which we now are reaſoning, the production of fixed air, or carbonic acid, in breathing, affords the ſtrongeſt preſumption, if not a direct proof, that there is a burning proceſs in the lungs of animals. In that caſe, it muſt be the ſpecies of light which we have termed *inviſible*, as having the power of heating without illuminating, which is made to emerge on this occaſion, when the phlogiſtic ſubſtance of the carbonic materials of the blood is decompoſed, by means of the vital air which is inſpired; for, upon no occaſion is heat the immediate production of that burning or oxigenating proceſs, ſo far as we know.

Here then is a purpoſe, in the animal oeconomy, for that conſtitution of things, in which there is a heating ſpecies of inviſible light to emerge in burning under certain circumſtances or conditions; and, here is a rational explanation, according to our principles, of animal bodies acquiring heat by means of reſpiration, or the breathing of cold atmoſpheric air,—perhaps it is the only explanation that may be given for that phenomenon.

That it is not the latent heat of the vital air, combined with the carbonic ſubſtance, that heats the lungs, muſt appear from this; that there is no reaſon to attribute more heat to that condenſation of vital air (in making the moſt liberal allowance for that heating power which is not known), than what is neceſſarily expended in this operation of the lungs, for evaporating water and heating the expired atmoſphere; theſe are much more than ſufficient to compenſate all the loſs of vital air, even ſuppoſing it to be concreted, which it is not, with the carbonic matter.

Therefore, there is perhaps every reaſon to conclude, That the heat, acquired in the breathing proceſs, ariſes from the conſumption of phlogiſton; and, in that caſe, it muſt be allowed, that it is a *burning* operation, and that it is *light* which here emerges for the purpoſe of heating bodies, and not for any purpoſe of illumination.

It muſt not be here alledged, that we cannot

not ſuppoſe a burning proceſs to proceed with ſuch a ſmall degree of heat;—we have many examples of ſuch a proceſs. One of theſe is the kindling of certain vegetable and animal bodies, when, under proper circumſtances, they are ſufficiently heaped together. In this caſe, the fire muſt have had its beginning in burning with a ſmall degree of heat, and thus increaſing the heating cauſe, as we have ſhown to be the caſe in burning coals. That it is not any ſimple heating cauſe which in this caſe brings thoſe bodies to the ſtate of incandeſcence, when the fire is commonly ſuppoſed to begin, may be made to appear. In the caſe of hay, for example, there is no heat produced if the vegetable bodies are ſufficiently dry; but, if heat is produced in conſequence of a proper degree of moiſture, all the humidity muſt be evaporated long before the heat arrives at that of boiling water; and then the heating cauſe would ceaſe. Now what a diſtance between this degree of heat and that which is the cauſe of bodies emitting red light viſible to us ? Therefore, it muſt have been by an inviſible burning, begun in a low degree of heat, that thoſe vegetable bodies had been brought to viſible fire.

Animal and vegetable bodies, in a certain ſtate of rotting, as well as phoſphorus expoſed to the cold atmoſpheric air, exhibit the plaineſt marks of burning with the ſmalleſt intenſity of heat, and of emitting light in conſequence of the decompoſition of phlogiſtic ſubſtance. But, I have a proof much more direct, which I ſhall now communicate.

Having calcined pure ſaw-duſt in a cloſs veſſel, to make charcoal, I ſuffered the maſs to cool, to ſuch a degree as that the heat was hardly, if at all, ſenſible to my hand which was then immerſed in it ; yet, notwithſtanding this coolneſs or low degree of heat, the maſs gradually took fire while I was handling it. How long this charcoal would have continued in that kindling ſtate, if not expoſed to the atmoſpheric air by opening the veſſel, I know not; it was the next day after the calcination that I opened it, and met with this unexpected phenomenon.

In this experiment of the charred ſawduſt, it appears, that the carbonic matter had been oxigenated by the atmoſpheric air, —that the phlogiſton had been decompoſed, or the fixed light been thus liberated, —and, that the charcoal bodies had been heated by the emerging light, which was then inviſible; and, all this operation of burning performed in a degree of heat not exceeding the temperature of the blood. This burning operation muſt then have proceeded to increaſe the heat of the ſurrounding ſmall charcoal bodies, by the extrication and emanation of inviſible light, until, by the progreſs of that ſecret fire, the ſolar ſubſtance had been accumulated in heat, and the heat augmented to ſuch a degree

gree as to emit viſible light, at which period it appeared, to common obſervation, as burning.

Now the queſtion is not How the illuminating and heating powers of light increaſe and diminiſh, according to the conditions in which that ſubſtance acts, but if this truly be the order of event, from which we have been forming a concluſion with regard to the final cauſe. In phyſical things, it is only from the effect that ever we judge either an efficient or final cauſe. Now we have been inveſtigating a certain order of things; and we have reaſoned upon that order as matter of fact, which may be aſcertained; in which caſe, the nature of light, or powers of that ſolar ſubſtance in relation to heat and viſion, may be demonſtrated, as well as that of gravitation, in which the intenſity of the power is variable with the diſtance.

Thus the wonderful conſtitution of light and heat (things always active and mutually convertible), may be traced through many proceſſes in the wiſe oeconomy of nature, or in the ſyſtem of this world, where ends and means are the proper ſubjects of our ſcience. Here we find powers ſo well adapted to the purpoſe of life, and purpoſes ſo properly adjuſted in the ſyſtem of the univerſe, connected by gravitation and extended by light, that, in caſes where our ignorance and limited capacity occaſion our taking only partial views, we have no reaſon to ſuſpect any defect of wiſdom in the contrivance, nor to entertain the leaſt diſtruſt with regard to the benevolence of the deſign.

This reaſoning, with regard to the end or final cauſe of that conſtitution which we have found in light, is here intended, not only to excite our admiration in ſeeing the works of Nature, but alſo to aſſiſt in directing our inquiry for the purpoſe of our ſcience. For, if we conſider it as in the ſyſtem of nature to diminiſh the heating power of the colouring ſpecies of light, in proportion as their luminous quality is increaſed by their compoſition in forming perfect light, or if their conſtitution be ſuch as to have their heating power decreaſing at a leſs rate, than that of giving viſion, when their intenſity is diminiſhed, then, it will be natural to look for the ſame conſtitution in the blue light of fire, as we have found belonging to the red ſpecies, that is, to have a greater power of exciting heat, proportionally to its power of giving light, when it is compared with the white ſpecies. Now this is a thing which we have it in our power to examine; conſequently, here would be an opportunity of trying our conjectured theory with regard to final cauſes, which can only be formed properly upon an inveſtigated law of nature.

Thus, in order to complete this theory with regard to the conſtitution of light, and its final cauſe, it would ſeem neceſſary to find the other ſimple ſpecies of light from fire, *i. e.* the blue ſpecies, alſo more powerful for exciting heat, comparatively with its power for viſion. This is a fact which I had intended to have aſcertained, by comparing the blue light of flame with the white light, in the ſame manner as I have done with the red light of fire. The method I propoſed, was to procure a ſufficient light of this kind, by a conſtruction of lamps burning weak ardent ſpirit; and then to meaſure the heating power of this light by which I ſhould be juſt enabled to read; I could thus compare it with the heating power of the white light, from a wax candle, diminiſhed by diſtance to the ſame intenſity for procuring viſion. Here is a field for experiment, that I now leave to others to undertake. In the mean time, let us reaſon upon the knowledge that we have procured.

So far as we have no doubt that it is the light of the ſun, compoſed of all the colouring

ing ſpecies, that is combined with the gravitating ſubſtances of this earth in the leaves of plants, for the production of phlogiſton the principle of fire, we have reaſon to preſume, that the rules, which we have found with regard to the action and affections of the light of fire, ſhould be alſo obſerved in that of the ſun; but this preſumption, in order to become a phyſical truth or principle, requires ſome proof; and now the queſtion is, How far the means are to be procured for ſuch a proof?

The light of the ſun is perfect, white, or compound light; and now we want to compare its more ſimple ſpecies with that compound light, as to their powers of exciting heat, that is to ſay, whether the heating power of the ſimple ſpecies is greater, in proportion to its power of giving viſion, than what ſhall be found in the compound light, as we have found to be the caſe with the light of fire. We have, therefore, firſt to ſeparate that compound light, in order to examine ſeverally its different ſpecies, and to meaſure their heating powers, when in the ſame intenſity for giving viſion, as that of the white compound light with which they are then to be compared.

Now, we have two ways for ſeparating the colouring ſpecies of ſolar light; firſt, by the refraction of priſmatic bodies; and, ſecondly, by means of the elective affections of light by colouring ſubſtances, in the tranſparent glaſs through which the light may be tranſmitted. The firſt would be by far the moſt perfect method, were it equally practicable as the other. But, in the ſecond method, we might eaſily procure both red and blue light, for the purpoſe of our experiment. How far our theory, with regard to the powers of light, ſhall be thus extended to the immediate influence of the ſun, I ſhall leave to the determination of natural philoſophers, who may undertake the taſk.

The great intenſity of heat which is procured by concentrating the light of the ſun with a lens of glaſs, may perhaps be conſidered either as inconſiſtent with that experiment of M. Mariote, when he applied his lens to the light of fire, and found that he only thus procured a very ſmall degree of heat, or as proving the difference of thoſe two kinds of light, that of the ſun and that of fire. But, before ſuch a poſitive concluſion could be formed, it would be neceſſary to have meaſured thoſe two things which are here compared, that is, the degree or intenſity of the ſun's light, and that of the fire light, which was concentrated by the lens. For, if the intenſity of the ſun's light as much exceeds that of the fire light, as the heat excited in the one focus exceeds that in the other, then ſo far from being found inconſiſtent, theſe two experiments would generaliſe the theory, with regard to light, which had been formed from the examination of fire alone.

I cannot determine how far this ſhall be found to be the caſe or not; but, this is certain, that the light of flame which appears to us, in the night time, to be ſo bright or luminous, diſappears when immediately compared with the light of the ſun. We have a ſimilar example in another caſe. The intenſity of the moon's light has been moſt ingeniouſly eſtimated comparatively with that of the ſun, and it is thus found that this light is of ſo ſmall a degree of intenſity, as to make the heat of its greateſt concentration to be a quantity perhaps imperceptible to our feeling, although, before that eſtimate was made, the moon's light had been thought to be ſo far different in its nature from that of the ſun, as not producing heat; whereas it is doubtful if this light of the moon does not give heat in the juſt proportion of its intenſity when compared with the light immediately from the ſun.

This compariſon properly ſuggeſts a queſtion with regard to the power of concentrated light, for exciting heat in bodies, viz. What rule does the power of light, for that purpoſe, obſerve?—Is the heat to be conſidered as ſimply or uniformly increaſing with the concentration of the light; or, is it according to another rule, that is, at a rate which is either increaſing or diminiſhing? Here is a queſtion of great importance in philoſophy. The reſolution of that queſtion might, perhaps, explain appearances with regard to different degrees of light, which otherwiſe ſhould ſeem to be anomalous.

If we are to reaſon from analogy in this caſe, we ſhould clearly decide the queſtion, in affirming, That the heat excited ſhould not be ſimply increaſing *uniformly* with the concentration of the light, but at a rate which ſhould be ſtill *increaſing*.

In Diſſertations upon Subjects of Natural Philoſophy, I have ſhown, firſt, that the power of heat, both for evaporating and for diſſolving bodies in general, increaſes, not uniformly, but at a rate which is ſtill increaſing. Secondly, I have ſhown, that the power of heat for dilating bodies, in which caſe it has to overcome the power of gravitation, does not increaſe only in the duplicate ratio inverſely of the diſtance, like that power which it then oppoſes, but at a rate which is ſtill higher; I have ſuppoſed it to be perhaps in the triplicate ratio. I have there alſo ſhown, that the uniting power of concretion increaſes ſtill at a higher rate. In this caſe, reaſoning from analogy, we ſhould be led to ſuppoſe, that the power of light, for exciting heat in bodies, ſhould not increaſe ſimply with the concentration or intenſity, but ſhould increaſe at a rate that were ſtill increaſing.

In order to ſee the force of this analogical argument, we are to conſider, that light and heat are two commutable modifications of the ſame ſolar ſubſtance, or of matter which acts upon the general principle of ſeparation, *i. e.* of repulſion; therefore, whatever

ever ſhall be found as belonging to the one may, in proper circumſtances, or ſo far as the nature of the modification admits, belong alſo to the other. But we have found, that the matter of heat acts more powerfully as the diſtances between its ſeveral parts, or of the parts of the body which it is to dilate, are diminiſhed, and that not ſimply in the ratio of the diſtance inverſely, but at a rate that is higher than the duplicate ratio. Now, the concentration, of the rays of light, is no other than diminiſhing the diſtance, among the parts of light which are impinging on the body to be heated by the irradiation; conſequently, according to the analogy of the caſe, the power of light, for heating the illuminated body, may moſt reaſonably be ſuppoſed as increaſing, with the concentration of the irradiated matter, at a rate which ſhould be ſtill increaſing.

In the ſcience of phyſics, analogical reaſoning leads properly to the making of experiment, by which the ſuppoſed principle of action, or phyſical truth, may be confirmed. Here, therefore, we are to inquire, how far there is any experiment, by which we might receive immediate information with regard to the ſubject now in queſtion, and by which our analogical reaſoning may be either confirmed or refuted.

There is an experiment, which I have long conſidered as proper for that purpoſe; it is an experiment which hitherto has been conſidered as giving an appearance altogether anomalous, upon the principles of chymical philoſophy; but this I believe has been little conſidered by chymical philoſophers. It is an experiment which has given occaſion to mechanical philoſophers forming an argument, in refutation of the chymical doctrine *that heat is a material ſubſtance;* and, from this experiment, thoſe mechanical philoſophers have been much confirmed in their doctrine, with regard to heat being nothing but *vibrations in the matter of bodies.* I ſhall now give a particular detail of this important experiment.

Two circular pieces of metal, ſuch as copper, are to be taken preciſely of the ſame diameter with that of the lens which is to be employed for concentrating the light. Theſe two equal metallic bodies are to be expoſed, at the ſame time, to be irradiated by the light of the ſun, tranſmitted through a plain glaſs to the one, and through the lens by which the light is to be concentrated in the middle of the other.

Here, then, is a caſe in which two equal bodies, of the ſame metal, are receiving equal quantities, as near as may be, of the ſolar light, and are reflecting apparently the ſame quantity of light; the only difference is, in this caſe, that the light is concentrated, and acts powerfully, or with increaſed intenſity, upon a portion of the one body, while the ſame quantity of ſolar light acts with a leſſer degree of intenſity upon all the ſurface of the other. Therefore, if the heating power of light increaſes equally with the concentration of its luminating power, or the intenſity of that light, the general heat of thoſe two bodies, acquired by that illumination, ſhould be equal; but, if the heating power ſhall increaſe at a greater rate than the luminous quality, when the intenſity of this light is increaſed by the concentration, then, the body illuminated through the lens ſhould become hotter on the whole, or receive a greater quantity of heat than the other which receives the light of leſs intenſity.

This experiment is one of thoſe which leaves no room for dubiety in the reſult; the increaſed heat, of the body illuminated by the lens, is incomparably greater than that of the other, even when this laſt is expoſed to the ſolar rays without the interpoſition of any glaſs. Thus, our concluſion, from analogy, is confirmed; and thus, the principles, on which we then had reaſoned, are farther proved, by an appeal to nature or matter of fact.

This opens a new field for the making of experiment. For, if it can be ſo contrived, to compare the heating powers of the light which comes from flame, in its ſimple and in its concentrated ſtate, as we have now done with regard to the light of the ſun; and, if the red and blue coloured light of fire can be alſo thus brought to the teſt of experiment, we ſhould then have an opportunity of trying the juſtneſs of our theory, and of more and more exploring the nature and conſtitution of light.

Whatever difference we may find between the immediate influence of the ſun, and the light which proceeds from fire, when theſe are to be converted into heat, or when theſe are examined with regard to their heating and illuminating powers, we cannot doubt of this, that the ſource of all our ſenſible heat is from the ſun, and that, without the influence of that great luminary, all fluidity would be at an end upon this earth, where every living thing would be locked up in ſolidity and death. We muſt alſo be perſuaded, that, were the influence of the ſun to be continually accumulated upon this globe, without abſtraction or return from this earth, the heat would increaſe, and become as deſtructive of animal and vegetable life, as would be the cold without the influence of the ſun.

But, beſides the immediate heat from the light of the ſun, there is another ſubject which requires the conſtant influence of the ſolar light.—Fire, and the conſumption of phlogiſtic ſubſtances, is a great and neceſſary operation in the oeconomy of this world. There is conſtant fire in the mineral regions;—fire which muſt conſume the greateſt quantity of fuel; the conſolidation of the looſe materials, ſtratified at the bottom of the ſea, depends upon the heat of that fire; and, the permanency of the land of this earth, above the ſurface of the ſea, depends upon that conſolidation of the ſtrata, and upon the great maſſes of ſtone which had been in a melted ſtate in the mineral regions. But, mineral fire muſt have for principle fixed light or phlogiſton, as well as the fire upon the ſurface of this earth, the nature of which we have been inveſtigating. Where then is the ſource of this light to be conſidered as placed, or from whence is this light to come, for the preſervation of this terraqueous world,—unleſs from the influence of the ſun?

This is an argument which, to be ſeen, requires to have made many ſcientific ſteps; and this is a ſubject which it is not in the way of every philoſopher to purſue. But now, I ſhall draw an argument from a ſubject which is within the reach of every natural philoſopher,—a ſubject which it is neceſſary to ſee, before that queſtion, now propoſed, can be properly reſolved.

The conſtitution of animal bodies neceſſarily requires phlogiſtic matter; for, thoſe bodies are chiefly compoſed of combuſtible and inflammable ſubſtances. At the ſame time, there does not appear to be any generation of that neceſſary ſubſtance in animal bodies; on the contrary, there appears to be a continual waſte of that ſubſtance, for the procuring of heat,—that heat which is neceſſary to animal life, and which, like that of fire, is produced by means of the oxigenating operation of atmoſpheric air. But, animal bodies receive this phlogiſtic ſubſtance in their food, which is all ultimately of vegetable production. Thus we are led to look for the ſource of phlogiſtic compoſition in the conſtitution of plants, for the growth of which the ſurface of this earth is ſo admirably contrived.

Upon examining accurately this ſubject, the growth of plants, we find, that, though vegetation proceeds in the dark, by means of heat and moiſture, yet, no phlogiſtic ſubſtance is produced, in thoſe living growing bodies, unleſs they are expoſed to the light of day; and, it is in the leaves of plants, which are ſo properly contrived for the arreſting of light, that this phlogiſtic ſubſtance firſt appears. But, this is not all; for, inſtead of having any of their ſubſtances oxigenated by atmoſpheric air, as is the caſe with breathing animals, vegetables ſecrete and emit that very oxigenating ſubſtance, when growing in the ſun, *i. e.* when, by means of the ſolar light, they are *compoſing* phlogiſtic ſubſtance in their leaves *.

We have thus ſatisfactory evidence, That it is the light of the ſun which is here ſtored up in the ſubſtance of vegetable bodies, as fixed light, or phlogiſton, the principle of fire. Conſequently, however this light, of our fire, may appear to differ in ſome ſmall reſpects from that which comes immediately from the ſun, we cannot ſuppoſe them as any way eſſentially different, but muſt conclude, that they are fundamentally the ſame, and that the light of the ſun, which is the principle of our fire, is continually flowing into this planet, for the purpoſe of actuating the terraqueous ſyſtem of this earth, and for enlivening animal and vegetable bodies.

---

* See Diſſertations upon Subjects of Natural Philoſophy, Part II.

I have long entertained certain views reſpecting the nature of light, which might here perhaps find a proper place; ſuch as, *e. g.* an inquiry into the nature of the ſeven priſmatic primitive ſpecies in the ſolar light, compared with thoſe compound ſeparable ſpecies which come from bodies, and which give us ſimilar ſenſations as the priſmatic orange and green that are not ſeparable into more ſimple conſtituent colours. But theſe inquiries are perhaps too ſpeculative or hypothetical to be claſſed with thoſe which we have been now conſidering, and with regard to which we have matter of fact to ſupport our theory.

I now conclude this long diſſertation, the chief object of which has been, to call the attention of philoſophers to that reaſoning in which the principles of ſcience are to be aſcertained, and natural philoſophy, which is founded on thoſe principles, of conſequence promoted.

I have here endeavoured to ſhow the nature of fire, as a thing depending upon light; and alſo the nature of light, in burning bodies, ſo far as not depending upon the heat of fire, but as being the principle of fire, or cauſe of heat in burning bodies. This is contrary to the commonly received notions of natural philoſophers, who have always conſidered the light of fire as proceeding from the heat of bodies. It is perhaps the prejudice of this received notion which has led chymical philoſophers of late, amidſt their valuable diſcoveries, to attempt the explanation of fire upon a certain principle, which, however true in itſelf and important in natural philoſophy, does not properly belong to that ſubject to which it was then inconſiderately applied.

If not attending to the natural order of things, and neceſſary conditions for the progreſs of our ſcience, we ſhall reaſon with regard to light and heat without analyſing ſufficiently our ideas upon the ſubject, ſo as to diſtinguiſh each of theſe from every other ſuch idea, we will only reaſon like the vulgar in miſunderſtanding things, however ingenious may be the thought, or however learned in other reſpects may be our ſcientific language; and, in that caſe, the ſcience of phyſics would loſe that certainty which conſiſts in ſeeing evidence, or in judging of every ſtep by which the underſtanding had proceeded for knowing the nature of things. Now to attempt to philoſophiſe with thoſe vulgar notions, or unanalyſed ideas, leads only to the confuſion of our knowledge, and to the formation of theories inconſiſtent with the natural order of things, to aſcertain which is the proper object of philoſophy.

MVSEVM BRITANNICVM

FINIS.